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Final Feasibility Study For Miscellaneous Sites (OU5) at the Umatilla Depot Activity (UMDA)

Submitted to:

U.S. Army Environmental Center
(USAEC),
Aberdeen Proving Ground,
Maryland

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Arthur D. Little, Inc.
Acorn Park
Cambridge, Massachusetts
02140-2390

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Arthur D Little

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Task Manager, Armand Balasco — Date: 15 Nov. 1993

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13. Abstract

This report presents the results of the Feasibility Study (FS) performed for the Miscellaneous Sites Operable Unit of Umatilla Depot Activity (UMDA) near Hermiston, Oregon.

From 1945 to the present, UMDA conducted various operations at the 32 sites identified as the Miscellaneous Sites. As a result of these activities, soil at some of these sites is contaminated with a variety of chemical compounds including explosives, pesticides, and metals.

This Feasibility Study addresses the contamination of soil at the Miscellaneous Sites; develops objectives for soil remediation; and identifies, develops, screens, and evaluates soil remedial action alternatives.

Basic components of the remedial alternatives subjected to a detailed evaluation for contaminated soil at the Miscellaneous Sites include: No Action; Institutional Control; Containment; On-Site Stabilization/Solidification; On-Site Incineration and Stabilization/Solidification; and Off-Site Treatment and Disposal.

An evaluation of remedial alternatives was conducted addressing the response of the alternatives to specific criteria including: Protection of human health and the environment; compliance with Applicable or Relevant and Appropriate Requirements (ARARs); long-term effectiveness and permanence; reduction of toxicity, mobility, and volume through treatment; short-term effectiveness; implementability; and cost.

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Acronyms and Abbreviations

ADA	Ammunition Demolition Activity Area
af	Acre Feet
amp	Amperes
APC	Air Pollution Control
ARARs	Applicable or Relevant and Appropriate Requirements
ATSDR	Agency for Toxic Substances and Disease Registry
BACT	Best Available Control Technology
BCF	Bioconcentration Factor
BRAC	Base Realignment and Closure
°C	Degrees Celsius
CA	Concentration in Air
CAA	Clean Air Act
CAG	Carcinogen Assessment Group, EPA
CBG/WB	Cemented Basalt Gravel/Weathered Basalt
cfs	Cubic feet per second
CE	Combustion Efficiency
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	Conversion Factor
CFR	Code of Federal Regulations
cm	Centimeter
CO	Carbon Monoxide
CRLs	Certified Reporting Limits
CS	Concentration in Soil

Acronyms and Abbreviations

CW	Concentration in Water
CWA	Clean Water Act
DAT	Drill and Transfer
DDD	Dichloro/Diphenyl/Dichloroethane
DDE	Dichloro/Diphenyl/Ethane
DDT	Dichloro/Diphenyl/Trichloroethane
DMRO	Defense Re-utilization Marketing Office
2,4-DNT	2,4 Dinitrotoluene
2,6-DNT	2,6-Dinitrotoluene
DNB	1,3-Dinitrobenzene
DoD	Department of Defense
DOE	Department of Energy
DRE	Destruction and Removal Efficiency
EA	Ecological Assessment
EMPA	Ethyl Methyl Phosphonic Acid
EPA	U.S. Environmental Protection Agency
EPIC	Environmental Photographic Information Center
°F	Degrees Fahrenheit
FFA	Federal Facility Agreement
FS	Feasibility Study
ft	feet
gpm	Gallons per Minute
GB	Non Persistent Nerve Agent

Acronyms and Abbreviations

H	Mustard Chemical Agent
HCl	Hydrochloric Acid
HEAST	Health Effects Assessment Summary Tables
HI	Hazard Index
HMX	High Melting Explosive (octahydro- 1,3,5,7-tetranitro-1,3,5,7-tetrazocine)
HQ	Hazard Quotient
HRS	Hazard Ranking System
ID	Induced Draft
IMPA	Isopypropyl Methyl Phosphonic Acid
in	Inch
IRIS	Integrated Risk Information System
K_d	Soil/Water Partition Coefficient
K_{ow}	Octanol/Water Partition Coefficient
K_p	Permeability Constant
KVA	Kilovolt Amps
lb	Pounds
LD_{50}	Lethal Dose to 50 Percent of the Study Population
LDR	Land Disposal Regulations
M	Million
MAIV	Mechanically Agitated In-Vessel
MCL	Maximum Contaminant Level
µg/g	Micrograms per Gram (parts per million)

Acronyms and Abbreviations

µg/l	Micrograms per Liter (parts per billion)
mg/kg	Milligrams per Kilogram (parts per million)
mg/L	Milligrams per Liter (parts per million)
MSL	Mean Sea Level
NAAQS	National Ambient Air Quality Standards
NB	Nitrobenzene
NCP	National Oil and Hazardous Substances Contingency Plan
NEPA	National Environmental Policy Act
NOAELs	No Observed Adverse Effect Levels
NPL	National Priorities List
NSR	New Source Review
ODEQ	Oregon Department of Environmental Quality
O&M	Operating and Maintenance
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
OU-1	Operable Unit Number 1 (Inactive Landfills)
OU-2	Operable Unit Number 2 (Active Landfill)
OU-3	Operable Unit Number 3 (Ground Water Contamination from the Explosives Washout Lagoons
OU-4	Operable Unit Number 4 (Ammunition Demolition Activity Area
OU-5	Operable Unit Number 5 (Miscellaneous Sites)
OU-6	Operable Unit Number 6 (Explosives Washout Plant)

Acronyms and Abbreviations

OU-7	Operable Unit Number 7 (Washout Lagoon Soils)
OU-8	Operable Unit Number 8 (Deactivation Furnace and Surrounding Soils)
PA	Preliminary Assessment
PCBs	Polychlorinated Biphenyls
PCC	Primary Combustion Chamber
PIC	Products of Incomplete Combustion
pg/m^3	Picograms per Cubic Meter
PHRED	Public Health Risk Evaluation Data Base
POHC	Principal Organic Hazardous Constituents
PPLV	Preliminary Pollutant Limit Value
PPMW	Parts per Million by Weight
PRGs	Preliminary Remediation Goals
PSD	Prevention of Significant Deterioration
psi	Pound per Square Inch
QA/QC	Quality Assurance/Quality Control
RA	Risk Assessment
RAC	Remedial Action Criteria
RAGS	Risk Assessment Guidance for Superfund
RAO	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act
RDX	Royal Demolition Explosive (hexahydro-1,3,5-trinitro-1,3,5-triazine)
RfD	Reference Dose

Acronyms and Abbreviations

RI	Remedial Investigation
ROD	Record of Decision
RTECS	Registry of Toxic Effects of Chemical Substances
SARA	Superfund Amendments and Reauthorization Act of 1986
SCC	Secondary Combustion Chamber
sec	Second
SF	Slope Factor
SPPPLV	Single Pathway Preliminary Pollutant Limit Value
TBC	To Be Considered
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total Dissolved Solids
TSDF	Treatment, Storage, and Disposal Facility
Tetryl	2,4,6-Tetranitro-N-methylaniline
THC	Total Hydrocarbon Concentration
TICs	Tentatively Identified Compounds
TLV	Threshold Limit Value
TOC	Total Organic Carbon
TNB	1,3,5-Trinitrobenzene
TNT	2,4,6-Trinitrotoluene
TSS	Total Suspended Solids
TWA	Time-Weighted Average
TWA	Total Waste Analysis

Acronyms and Abbreviations

UMDA	Umatilla Depot Activity
USAEC	U.S. Army Environmental Center
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
UXO	Unexploded Ordnance
V	Volts
VX	Persistent Nerve Agent
yd^3	Cubic Yards
yr	Year

1.0 Introduction

This report presents the results of the Feasibility Study (FS) performed for Operable Unit 5 (Miscellaneous Sites) of Umatilla Depot Activity (UMDA) near Hermiston, Oregon. This report was prepared by Arthur D. Little, Inc. for the U.S. Army Environmental Center (USAEC), formerly the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) under Task Order No. 2, Contract No. DAAA15-91-D-0016. The FS has been conducted in accordance with the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986 and its governing regulations, the National Contingency Plan (NCP) 40 CFR Part 300.

Eight operable units (OUs) have been identified at the UMDA site based on the results of the Preliminary Assessment (PA)[1] and the Remedial Investigation (RI)[2]:

- Inactive Landfills
- Active Landfill
- Ground Water contamination from the explosives washout lagoons
- Ammunition Demolition Activity Area (ADA)
- Miscellaneous Sites
- Explosives Washout Plant (Building 489)
- Washout Lagoon Soils
- Deactivation Furnace and surrounding soils

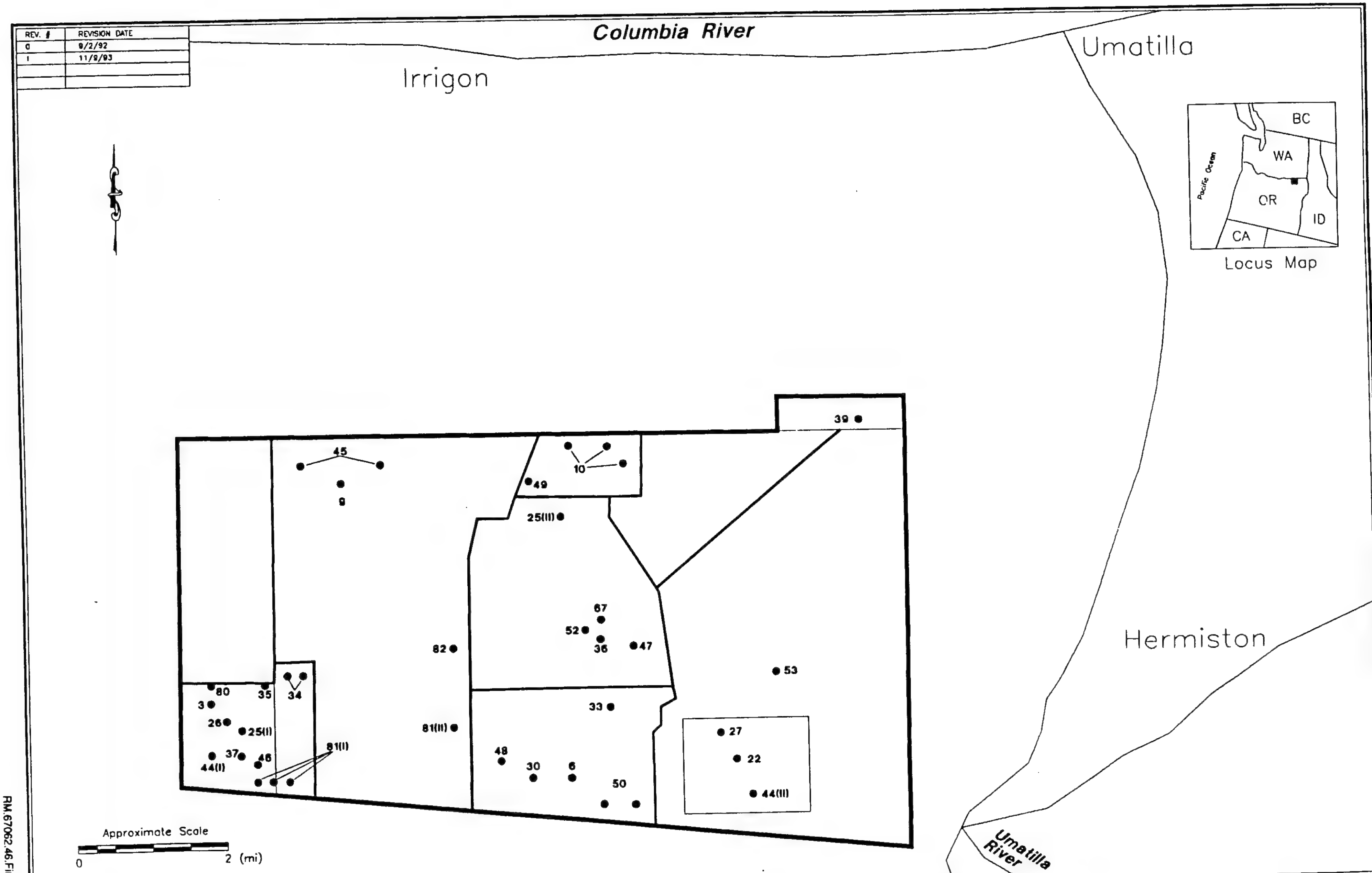
This FS is focused on the evaluation of remedial alternatives for 32 sites at UMDA that are grouped together as the Miscellaneous Sites Operable Unit (OU-5) and that have relatively low levels of contamination. The other seven OUs will be evaluated in separate FS reports.

1.1 Purpose and Organization of Report

1.1.1 Purpose

UMDA is a U.S. Army ordnance depot located near Hermiston, Oregon. From the 1940s until present, UMDA operated periodically at the 32 miscellaneous sites identified as OU-5. The U.S. Army wishes to assess the status of each site and accordingly plan the remediation as appropriate of any or all of the 32 sites. As part of this process, this FS details the actions proposed for the sites.

The 32 sites of OU-5 are located throughout UMDA as shown in Figure 1-1. Many of the sites are clustered in the southwestern and southern portion. The southwestern cluster of sites centers on warehousing, railroad unloading, and stockpiling activities. The southern portion of UMDA includes the administrative areas as well as support activities such as sewage treatment and storm water discharges that are responsible for a cluster of OU-5 sites. The remaining OU-5 sites are spread throughout UMDA and relate to a variety of mission activities and support facilities for mission activities.



PREPARED FOR: USAEC		DRAWN BY: (INITIALS)	Arthur D Little
DATE: NOV. 93	SCALE: AS SHOWN	DWG. NO. 67062-010	APPROVED BY: (INITIALS)

TITLE: Figure 1-1: UMDA Operable Unit 5 Site Locations

1.0 Introduction

This FS addresses the contamination concerns at the Miscellaneous Sites Operable Unit (OU-5); develops objectives for soil remediation; and identifies, develops, screens, and evaluates soil remedial action alternatives. Remedial alternatives pertaining to ground water are not addressed in this FS (see Section 1.2.5.4.3 of this FS). However, overall risks for the OU-5 sites include those relating to exposure to ground water and preliminary remediation goals (PRGs) are identified accordingly.

This FS follows the guidelines provided in the EPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*[3], including defining the contamination problems; formulating remedial action objectives for the sites; and developing, screening, and evaluating soil remedial action alternatives. The results of this evaluation will be used by the Army, in consultation with the Environmental Protection Agency (EPA) and the Oregon Department of Environmental Quality (ODEQ), to select and propose a preferred remedial action for the Miscellaneous Sites. After the Proposed Plan is reviewed by the public, the Army and the EPA will formalize the soil remedial action decision in a Record of Decision (ROD) with concurrence from ODEQ. A similar process will be followed for the seven other OUs.

The NCP encourages the evaluation of innovative technologies where they might offer the "potential for comparable or superior treatment performance or implementability, fewer or lesser averse impacts... or lower costs for similar... performance than demonstrated technologies" [40 CFR 300.430 (a)(1)(iii)(E)]. As a baseline for these technologies, the impact of taking no action at the site is also presented. Other potentially applicable remedial technologies are discussed in the technology evaluation and screening sections.

The FS is also intended to satisfy the requirements of section 102(2)(C) of the National Environmental Policy Act of 1969 (NEPA). The FS evaluated both the short-term and long-term impacts of several alternatives, including no action. In addition, a NEPA-type public review will take place after completion of the FS and Proposed Plan and prior to issuance of the ROD.

1.1.2 Organization

As the first step in the FS development process, existing data on UMDA and Miscellaneous Sites were compiled, summarized, and interpreted. These data are presented in Section 1.2, Background Information. This background serves to establish an historical and physical perspective of the sites as well as to provide an understanding of the nature and extent of the contamination. In addition, these data were used as the basis for the conduct of the Human Health Baseline Risk Assessment (RA)[4] which is summarized in Section 1.2.

Based on the interpretations and analyses of site-related data, remedial action objectives were defined and possible general response actions and associated remedial technologies were identified. The response actions and the remedial technologies were screened; first for general feasibility, and then in more detail on the basis of effectiveness,

implementability, and cost. The remedial objectives and the results of the screening procedure are presented in Section 2.4, Identification and Screening of Technology Types and Process Options.

The results of the identification and screening analysis were used to develop remedial alternatives to be carried through detailed analyses. These alternatives consist of individual technologies and process options as well as appropriate combinations of technologies and process options. These alternatives and the rationale used to develop them are presented in Section 3.0, Development of Alternatives.

In Section 4.0, Detailed Analysis of Alternatives, the evaluation of each of the selected remedial alternatives is described. This evaluation addresses criteria specified in the NCP including: overall protection of human health and the environment; compliance with Applicable or Relevant and Appropriate Requirements (ARARs), long-term effectiveness; reduction of toxicity, mobility, or volume; short-term effectiveness; implementability; and cost. Following the summary of the response of each alternative to these criteria, all of the alternatives are compared to identify strengths and weaknesses to allow for an informed decision to be made with respect to the selection of the most appropriate alternative to be pursued.

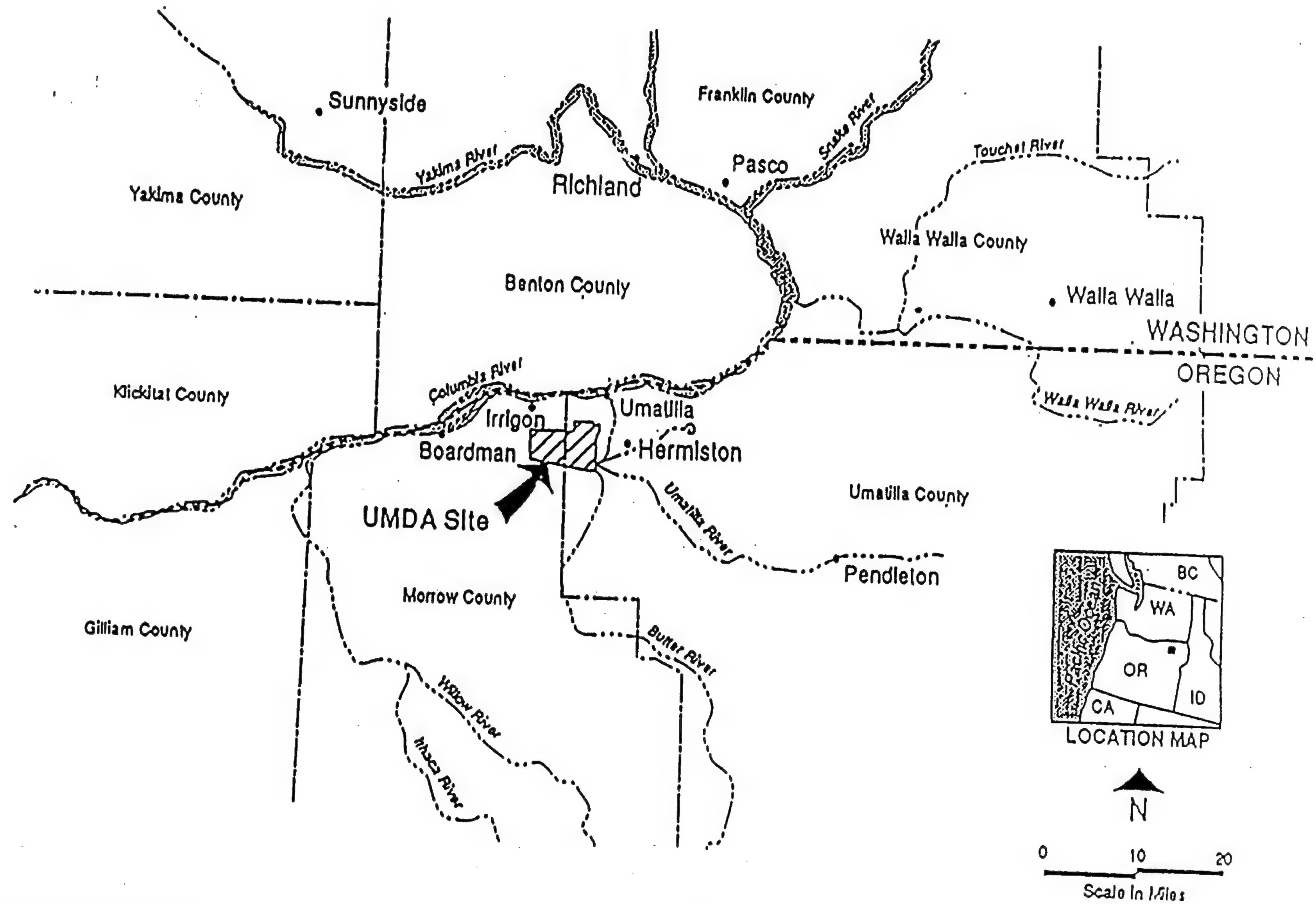
1.2 Background Information

This section describes the background and physical setting of UMDA and the Miscellaneous Sites including the nature and extent of the existing contamination at the Miscellaneous Sites. The primary references used in developing this background information are the installation-wide Preliminary Assessment[1] and the RI.[2] Also included in this section is a summary of the Human Health Baseline Risk Assessment.[4]

1.2.1 Site Location and History

UMDA is located in northeastern Oregon on the border of Umatilla and Morrow counties near the city of Hermiston as shown in Figure 1-2. It was established by the Army in 1941 as an ordnance facility for storing conventional munitions. Subsequently, the function of the facility was extended to include ammunition demolition (1945), renovation (1947), and maintenance (1955). In 1962, the Army began to store chemical-filled munitions and containerized chemical agents at the facility. UMDA continues to operate today as a munitions storage facility, and will be conducting activities associated with the Army's Chemical Demilitarization and Installation Restoration Programs.

The facility occupies a roughly rectangular area of 19,728 acres; 17,054 acres are owned by the U.S. Government, while the remainder are controlled by restrictive easements that provide a safety zone around the facility. Although ownership of the latter is private, the easements grant perpetual rights to the U.S. Government, including the right to prohibit human habitation and to remove buildings. The owners retain the right to farm the lands and to graze livestock.



PREPARED FOR: UMATILLA Washout Plant FS			SOURCE: Umatilla Depot Activity Washout Lagoons Soil Record of Decision (Sept. 1992)
DATE: Feb.. 1993	SCALE: AS SHOWN	DWG. NO. 67062-010	TITLE: Figure 1-2: Facility Location Map Umatilla Depot Activity

The UMDA facility is currently one of several installations scheduled for realignment under the Department of Defense (DoD) Base Realignment and Closure (BRAC) program. Under this program, the Army will eventually vacate the installation and relinquish ownership to another governmental agency or private interests. Although future use of the installation in general has not been determined, light industrial or residential use is a possibility.

The 32 Miscellaneous Sites are located throughout UMDA. These sites have served a wide variety of functions, including: sewage treatment and storm water discharges, munitions disassembly, defense reutilization marketing area, ground storage of strategic materials, metal ingot storage, pesticide storage, paint spray and shot blast area, plant sludge discharge area, boiler/laundry effluent discharge sites, disposal pits, and hazardous waste storage. Typical activities conducted at the Miscellaneous Sites have involved a range of chemical compounds and metals, including:

- Explosives contained in ordnance being burned, detonated, or disposed (2,4,6-trinitrotoluene [TNT]; 1,3,5-trinitrobenzene [TNB]; 2,4- dinitrotoluene [DNT]; hexahydro-1,3,5-trinitro-1,3,5-triazine [RDX]; and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine [HMX])

- Metals (e.g., lead, chromium, antimony, cadmium, copper, mercury, and nickel) contained in ordnance and munition casings being burned, detonated, or disposed of

- Pesticides (e.g., chlordane, DDD, DDT, and DDE) applied or disposed of and polychlorinated biphenyls (PCBs) from old transformers

1.2.2 Site Description

1.2.2.1 Regional and Installation Setting

1.2.2.1.1 Topography and Surficial Geology. The portion of Oregon within an approximate 50-mile radius of UMDA includes parts of two geomorphic regions:[5] the Deschutes-Umatilla Plateau and the Blue Mountains (Figure 1-3). Both of these regions lie at least partly within the Umatilla River Basin.

The Deschutes-Umatilla Plateau has relatively little relief. It gradually rises southward from elevations near 260 feet mean sea level (MSL) at the Columbia River to approximately 800 feet at the foot of the Blue Mountains. Near-surface deposits underlying the Plateau consist primarily of Miocene basalt flows, basalt debris, and silts deposited as alluvial fans, Quaternary silts and clays, and Quaternary alluvial gravel and sand deposited by catastrophic flooding of the Columbia River.[5]

The edge of the Blue Mountains lies approximately 40 miles south and southeast of UMDA. The Blue Mountains reach elevations ranging from 3,500 to 6,000 feet. The mountains are considerably dissected by streams, which have eroded many steep-walled

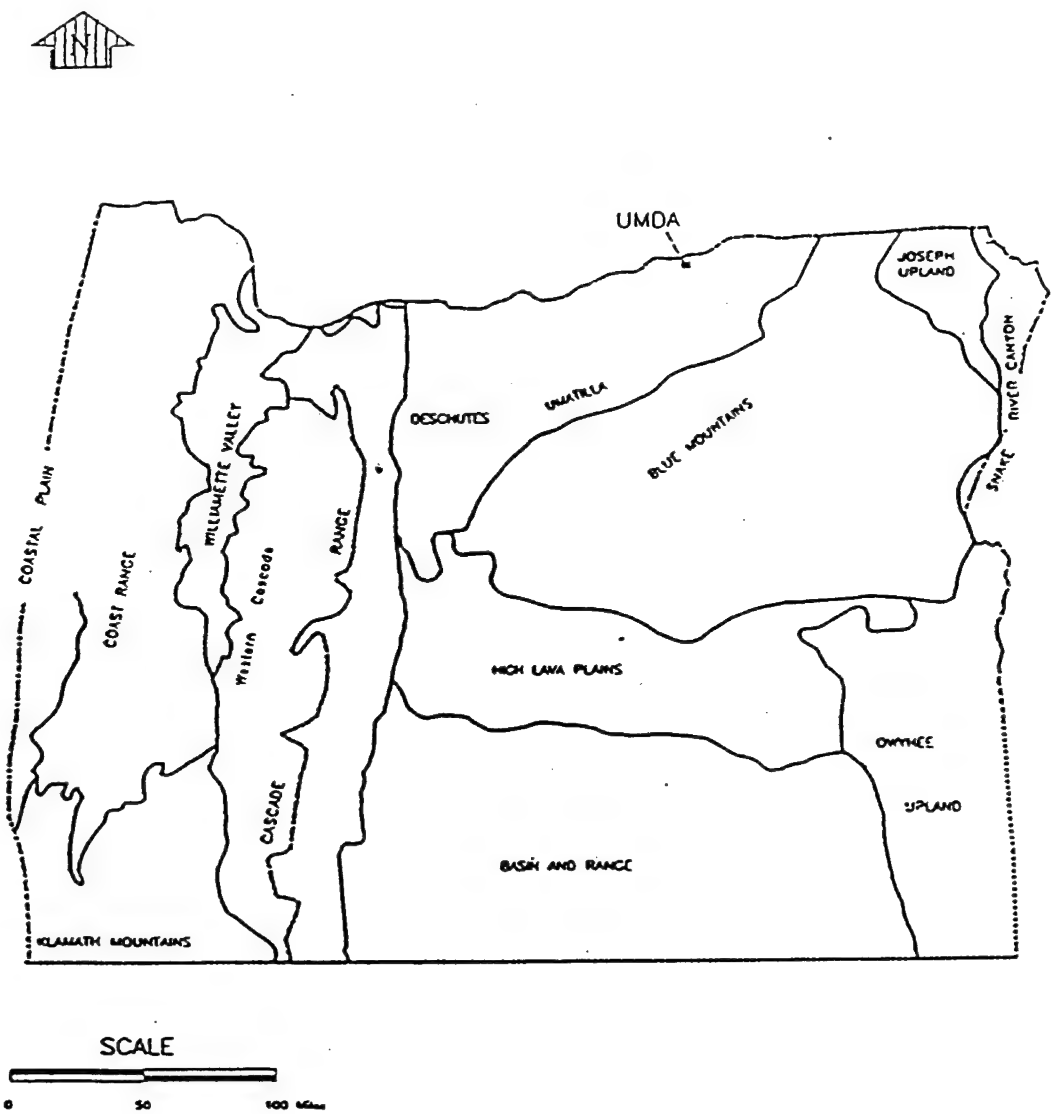


Figure 1-3: Geomorphic Regions of the Area near UMDA. UMDA lies within the Deschutes - Umatilla Plateau.

TITLE		
FIGURE 1-3: GEOMORPHIC REGIONS OF THE AREA NEAR UMDA		
PREPARED FOR: UMATILLA	SOURCE: AFTER WALKER, 1977, AS MODIFIED FROM DICKEN, 1950	
DATE: OCT. 1992	SCALE AS SHOWN	DWG. NO 67062-014

canyons.[6] Near-surface deposits are primarily basalt and rhyolitic tuffs, with smaller areas of metamorphosed sedimentary and volcanic rocks of probable Triassic age, and diorite and other intrusive rocks of provable Cretaceous age.

The topography of the UMDA site, illustrated in Figure 1-4, can be naturally divided into three areas: Coyote Coulee; sloping lands east of the coulee; and rolling hills west of the coulee.

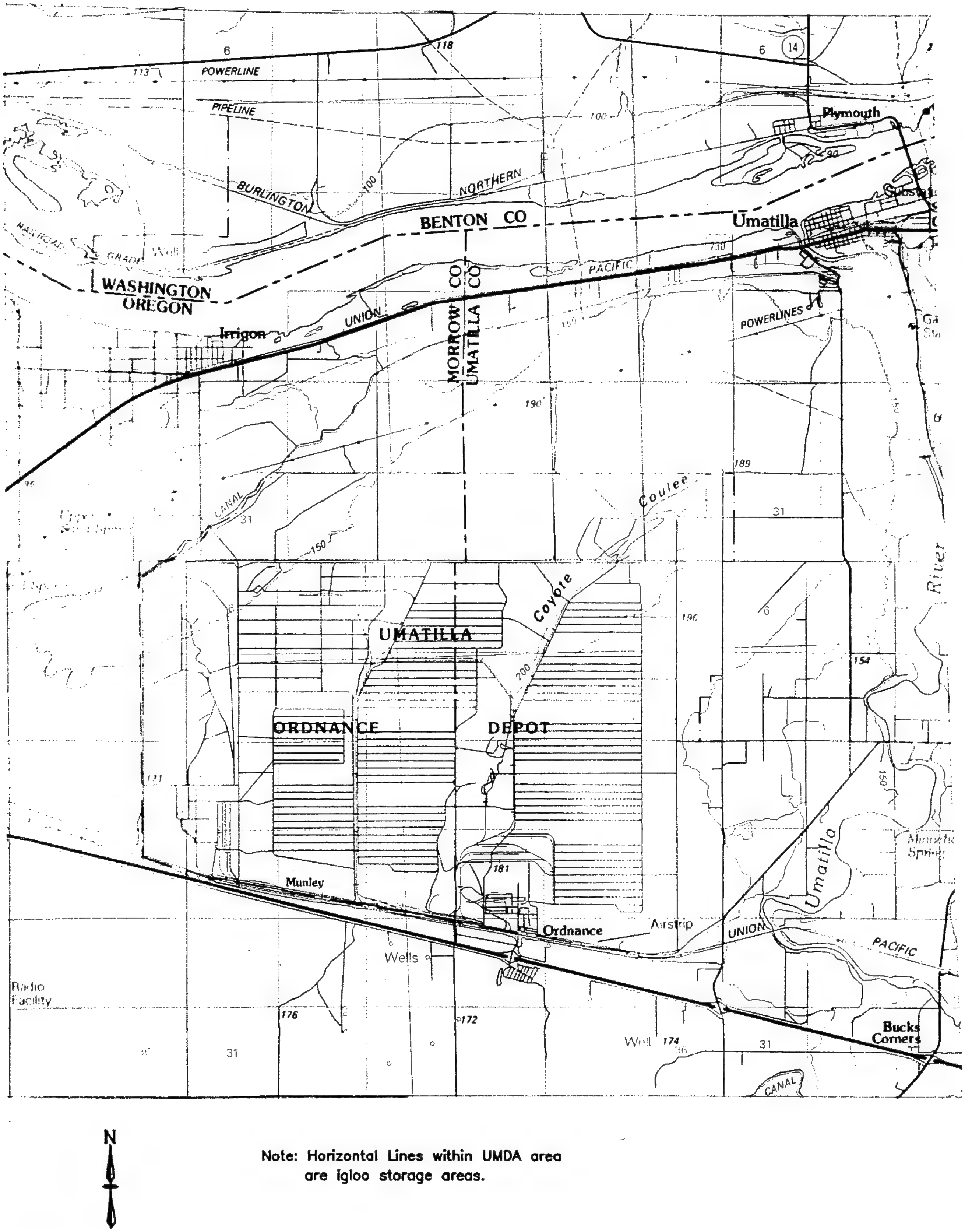
Coyote Coulee is a linear depression, about 0.25 mile wide, that trends north-northeast to south-southwest across UMDA. About one-third of UMDA lies east of Coyote Coulee. The east side of the coulee is a steep escarpment about 50 feet high. Although the land rises westward from the bottom of the coulee, the top of the escarpment is at a higher elevation than any nearby land west of the escarpment along most of the length of the coulee. The coulee is thus asymmetrical, unlike an erosional canyon where the elevation of the top of both canyon walls is generally the same. The top of the escarpment is near 650 feet in the north half of UMDA, but slopes southward to 600 feet near the southern boundary. The escarpment vanishes quite abruptly at the southern boundary.

East of Coyote Coulee, the surface slopes smoothly to the southeast, away from the escarpment, at a slope of approximately 50 feet per mile (ft/mi). The principal exceptions are a low hill near the southeast corner of UMDA, and a nearly level area around the administration area. West of Coyote Coulee, the surface consists largely of rolling hills. The highest hill (677-foot elevation) is near the northern boundary, just west of Coyote Coulee. A broad area of high ground extends to the southwest from this hill; from the high ground, the surface slopes, with many irregularities to the northwest and south.

The northern half of the area west of Coyote Coulee has many linear hills and valleys, trending east-northeast to west-southwest, 10 to 20 feet high and up to 0.5 mile in length. These features may be large ripples associated with catastrophic flooding that occurred during drainage of Glacial Lake Missoula.

No natural streams occur within UMDA because of highly permeable soil. Drainage patterns are very poorly developed because of highly permeable soil, low precipitation, and the recent formation of the landscape. No direct information on storm water drainage is available for most of UMDA. Storm water runoff apparently does not travel far, except near the administration area, where runoff is collected by storm sewers. Many areas of closed drainage exist, particularly west of Coyote Coulee, with the largest about 100 acres in size. Surface water runoff generally follows topography and flows in a north-northwest direction. Drainage patterns are poorly developed.

1.2.2.1.2 Stratigraphy. This section provides an overview of the stratigraphy of UMDA, discussing only the geological units investigated by drilling during the RI and previous on-post investigations as well as a recently completed post-RI investigation[6]. The geology of the Miscellaneous Sites conforms to the stratigraphy of the UMDA region.



Note: Horizontal Lines within UMDA area are igloo storage areas.

PREPARED FOR: UMATILLA			**Figure 1-4: Topography of UMDA** Source: USGS
DATE: March 1993	SCALE: 1:100,000	DWG. NO.: 67062-022	

As described in the RI, three distinct geologic units underlie UMDA. These are, from oldest to youngest, unweathered to moderately weathered basalt flows and associated interbed deposits of the Columbia River basalts; "cemented basalt gravel/weathered basalt" (CBG/WB) and underlying gravel; and unconsolidated alluvium. However, recent investigations have indicated that the CBG/WB is actually the first basalt layer (Elephant Mountain Member) and represents a confining layer for the Rattlesnake Ridge Interbed as shown in Figure 1-5.

Columbia River Basalt Flows and Interbeds. The unweathered to moderately weathered basalt flows and associated interbed deposits are lithologically consistent (but not homogeneous), and laterally continuous across UMDA. In general, the tops of the basalt flows are moderately weathered, vesicular, and highly fractured. This zone grades downward to less weathered, massive basalt with fewer fractures. The base of the basalt flows is relatively sharp. Permeable interbed deposits lie between the massive basalt flows. The interbeds are much thinner than the basalts and are derived from weathered basalt gravel and possibly other sedimentary materials It is difficult to distinguish basalt-derived sedimentary interbeds from weathered flow tops on the basis of drill cuttings and video logs.

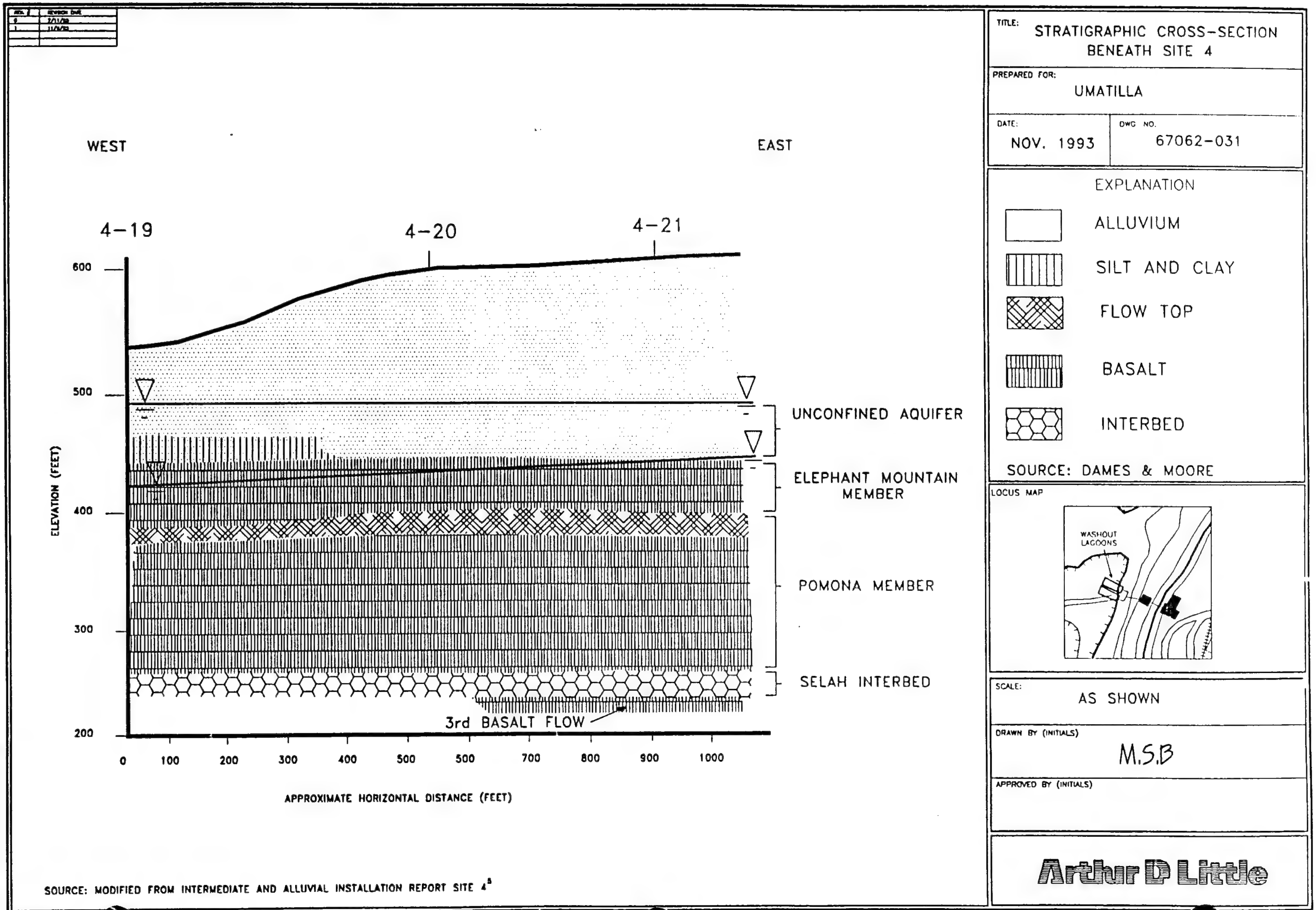
A total of six individual basalt flows and associated interbeds have been penetrated by on-site wells. The first unit informally referred to as the CBG/WB in the RI has been determined to be the Elephant Mountain Member in the post-RI investigation. The Elephant Mountain Member is underlain by approximately 30 feet of basalt-derived unconsolidated sands and gravels identified as the Rattlesnake Ridge Interbed. These gravels appear to be distinct from the overlying flood-deposited alluvial gravels, which are generally more rounded and contain a greater variety of source rock types.

The second basalt flow is the thickest encountered, having an approximate thickness of 170 feet. This unit is interpreted to be the Pomona Member of the Saddle Mountain Basalt, based on stratigraphic characteristics and position in geologic sequence. This basalt flow is underlain by a thinner interbed horizon, which is interpreted to be the Selah Interbed of the Ellensburg Formation. The four deep monitoring wells at Site 4 are completed in this interbed. Where fully penetrated on UMDA, the thickness of the Selah Interbed ranges from 20 to 70 feet.

The Selah Interbed is underlain by another basalt flow and associated interbed, which are interpreted to be the Umatilla Member of the Saddle Mountain Basalt and the Mabton Interbed of the Ellensburg Formation, respectively. Only two water supply wells fully penetrate both the Umatilla Member and the Mabton Interbed; the thicknesses of these units in these two supply wells are approximately 50 and 25 feet respectively.

These two water supply wells also penetrate at least three more thin basalt flows and associated interbeds below the Mabton Interbed. These thin basalt flows are interpreted to consist of the upper portion of the Frenchman Springs Member of the Wanapum Basalt. The Frenchman Springs Member is composed of several individual basalt flows

Figure 1-5



WEST
EAST
4-19
4-20
4-21
600
500
400
300
200
ELEVATION (FEET)
0
100
200
300
400
500
500
700
800
900
1000
APPROXIMATE HORIZONTAL DISTANCE (FEET)
UNCONFINED AQUIFER
ELEPHANT MOUNTAIN MEMBER
POMONA MEMBER
SELAH INTERBED
3rd BASALT FLOW
SOURCE: MODIFIED FROM INTERMEDIATE AND ALLUVIAL INSTALLATION REPORT SITE 4[5]
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EXPLANATION
ALLUVIUM
SILT AND CLAY
FLOW TOP
BASALT
INTERBED
SOURCE: DAMES & MOORE
LOCUS MAP
WASHOUT LAGOONS
SCALE: AS SHOWN
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Arthur D Little

separated by unnamed interbeds of the Ellensburg Formation. A total thickness of over 230 feet of basalt flows belonging to the Frenchman Springs Member and associated unnamed interbeds is encountered in these two deep supply wells.

The top of basalt (i.e., Pomona Member) occurs beneath UMDA at elevations ranging from 300 to 404 feet above MSL, based primarily on the borehole geophysical logs. The top of basalt is relatively flat across most of the installation. However, depths encountered in water supply wells (supply-6 & -7) are significantly deeper, indicating that the basalt dips northward in the vicinity of these wells.

Alluvium. The alluvium consists of unconsolidated clay, silt, sand, and gravel containing cobbles up to at least six inches in diameter. These sediments probably represent catastrophic flood deposits and associated lower energy deposits in "quiet" waters. Lithologically, the unconsolidated detritus consists of quartzitic, felsic, and basaltic clasts. Throughout UMDA, sands or gravel are generally encountered at the surface. These deposits tend to become finer grained with depth, typically grading to sandy or clayey silts near the base of the alluvial section at its contact with the CBG/WB. Silt and clay beds up to tens of feet thick occur near the bottom of the alluvium in some parts of the installation (e.g., Site 11). Coarser sands and gravels extend to a greater depth in the southern portion of UMDA, with a layer of silty clays still present above the CBG/WB. The angular basalt gravel underlying the CBG/WB is not considered part of the alluvium, because it appears to be of a different age and origin.

The thickness of the alluvial section penetrated in monitoring wells at UMDA ranges from approximately 42 feet in the northern part of the ADA area to 173 feet at Site 11. In addition, a thickness in excess of 200 feet was estimated in one of the water supply wells based on borehole geophysical logs. Most of this variation is due to differences in surface elevation; the elevation of the base of the alluvium varies less than that of the land surface.

1.2.2.1.3 Hydrogeology. Ground water occurs beneath UMDA in a number of distinct hydrogeologic settings; in a series of relatively deep confined basalt aquifers and in a highly productive permeable unconfined aquifer in the south of UMDA (extending off post). Geologically, the confined basalt aquifers consist primarily of the flow top interbeds between unweathered basalt flow interiors. The basalt flow interiors act as confining layers separating the interbed aquifers; however, structural discontinuities may be present within these flow interiors, providing local, vertical hydraulic connections between flow top aquifers. The unconfined aquifers consist of the saturated permeable alluvium and the saturated silty alluvium. The CBG/WB and the underlying gravels were originally thought to be part of this unconfined aquifer; however, that interpretation has been revised based on post-RI investigations and this layer is now considered to be the Rattlesnake Ridge Interbed. A representative cross section illustrating the major hydrogeologic features of Site 4 at UMDA is presented in Figure 1-5.

Confined Basalt Aquifers. Ground water occurrence in the basalt is primarily within interbed units consisting of gravels and vesicular flow tops lying between basalt flows. Ground water is under confined conditions in these basalt aquifers. Based on borehole geophysical logs of water supply wells supply-6 and supply-7 (i.e., the deepest on-post wells), as many as five confined aquifers could be present beneath UMDA between ground surface and a depth of 700 feet. However, the four deep basalt monitoring wells at Site 4 and approximately half of the water supply wells penetrate only the uppermost confined aquifer, which occurs in the Selah Interbed. This aquifer appears to be continuous beneath UMDA and to extend beyond the installation boundaries. The lateral extent of the underlying interbeds (confined aquifers) beneath UMDA is largely unknown due to the lack of deep wells that penetrate them.

The interbeds are fairly productive aquifers, yielding 29.5 gpm for a period of eight hours at Site 4 and could have produced more if the pump had been set deeper in the well. Large yields are obtainable from water supply wells that penetrate one or more interbeds. Water supply well supply-1, for example, is capable of producing 1,000 gpm with 10 feet of drawdown[9]. Therefore, this well has a relatively high specific capacity of 100 gpm/ft. Supply-5 and supply-7 have even higher specific capacities -- 133 and 130 gpm/ft, respectively -- but are limited to smaller yields of 500 and 650 gpm by the capacities of their pumps.

The unweathered basalt flows act as confining beds or leaky confining beds to retard vertical movement of water between the alluvium and basalt interbeds and, apparently, between different interbeds. Structural discontinuities may be present to provide local hydraulic connections between flow top aquifers. The vertical hydraulic conductivity of the basalt has not been measured at UMDA. However, permeability data for flow interiors are available for the Hanford site in Washington[10]. Reported horizontal permeabilities range from 1×10^{-7} to 1×10^{-10} cm/sec. Field-derived vertical permeability estimates are not available from Hanford. Based on simulations and statistical analyses of fracture data, the U.S. Department of Energy (DOE) estimates that vertical permeabilities will be found to be within a factor of 10 of the horizontal conductivities.

Unconfined Aquifer. As previously stated, the unconfined aquifer at UMDA consists of the sand and gravel of the alluvium and the silty clay of the alluvium. Areally, unconfined ground water occurs in two distinct hydrogeologic units beneath UMDA: a permeable southern aquifer (termed the Ordnance Aquifer) and a less permeable northern aquifer. The behavior of ground water in these two aquifers is distinctly different.

Ordnance Aquifer. The Ordnance Aquifer is located in the southern portion of UMDA and extends off post both to the south and to the east, corresponding to the "Ordnance Critical Ground Water Area." To the south of UMDA, the aquifer is tapped by numerous shallow wells that produce as much as 1,000 gallons per minute. Although regional water levels have declined since initiation of irrigation pumping in the 1950s and 1960s, the specific capacities of these irrigation wells are high. The use of the aquifer has been

the subject of regional studies to evaluate the impact of withdrawals and artificial recharge activities[11]. Ground water levels in the Ordnance Aquifer have shown a net annual increase since the initiation of artificial recharge activities and reduced pumping in the 1970s.

Permeabilities of shallow wells in the southern part of UMDA (Ordnance Aquifer) are typically much greater than in wells to the north. Average permeability values from wells in the Ordnance Aquifer at Sites 4 and 12 are on the order of 2.1×10^{-1} cm/sec (585 ft/day), with a maximum of 9.6×10^{-1} cm/sec (2,721 ft/day). Ground water gradients within the Ordnance Aquifer are very low (approximately 0.00015 ft/ft), further suggesting high aquifer permeabilities. An evaluation of hydrographs from the Ordnance Aquifer monitoring wells at Sites 4 and 12 shows a significant seasonal response to off-post pumping and artificial recharge activities to the south and east of UMDA.

The saturated thickness of the Ordnance Aquifer is known only at Site 4, where four monitoring wells penetrate through to the Pomona Member. At this site, the saturated thickness of the entire unconfined aquifer ranges from approximately 100 to 127 feet. These estimates include the entire saturated thickness of the alluvium, the CBG/WB, the underlying gravel, and the upper 10 feet of the Pomona Member (which is fractured and moderately weathered).

Ground water flow directions in the Ordnance Aquifer reverse seasonally in response to off-post pumping and recharge activities. During the summer and early fall, flow is toward the east and south as irrigation activities peak. During the winter and early spring, when irrigation activities are at a minimum, ground water flow is to the north and west. It is probable that, prior to initiation of irrigation in the 1950s and 1960s, the natural direction of flow in the Ordnance Aquifer was to the northwest toward the Columbia River and in the direct vicinity of the Umatilla River, possibly to the northeast. Currently, because water level declines have occurred in the aquifer, discharge is probably exclusively to irrigation wells. There is likely insufficient head now to drive ground water either into the finer sediments of the northern aquifer or over the top of the finer sediments within the more permeable sediments (which are now dewatered and overlie the finer northern aquifer sediments).

Northern Aquifer. The Northern Aquifer pinches out along an east-west transect slightly north of Site 4. Ground water gradients to the south of this contact are low and reverse seasonally in response to off-post stresses. Ground water gradients to the north of this contact are much greater (0.0085 ft/ft) and show no seasonal reversals. Flow is consistently to the northwest, where it probably discharges to the Columbia River. Hydrographs of selected wells indicate that the wells do not respond to off-post irrigation activities, suggesting that they are not in hydraulic contact with the Ordnance Aquifer. Northern aquifer permeabilities are typically much less than those to the south, with an average value of 9.5×10^{-3} cm/sec (27 ft/day) and a maximum value of 1.8×10^{-1} cm/sec (503 ft/day).

The saturated thickness of the northern aquifer beneath UMDA, exclusive of the Elephant Mountain Member, is about 30 to 60 feet in most places. In the UMDA area, the alluvium reaches a maximum saturated thickness of 70 feet; but it is zero in the north, where the elevation of the top of the Elephant Mountain Member is above the water table.

1.2.2.1.4 Streams Within the Umatilla Basin. UMDA is located in the Umatilla Basin. The basin's area is about 2,545 square miles[13]. The principal stream is the Umatilla River, whose principal tributaries rise in the Blue Mountains and flow generally northward toward the Columbia River, which bounds the basin to the north. The Columbia is a major river in the area, with a mean discharge of 200,000 cubic feet per second (cfs)[11]. Its level is stabilized at an approximate elevation of 265 feet by the John Day Dam.

Mean discharge of the Umatilla River (located approximately 1 to 2 miles east of the installation boundary, depending on location) at Yoakum, 17 miles downstream from Pendleton, was 669 cfs from 1935 to 1985[13]. A lower gage at Umatilla, near the mouth of the river, has a considerably smaller mean discharge, 490 cfs, because of irrigation diversion, and does not reflect natural streamflow. Butter Creek, the largest tributary in the area of the Umatilla Basin, has a mean discharge of 28 cfs at Pine City, 20 miles above its junction with the Umatilla River.

Streamflow varies considerably through the year. At Yoakum, mean flow is 1,665 cfs during April, but decreases steadily to 91 cfs in October. During the irrigation season, most streamflow in the Umatilla River and Butter Creek is diverted for irrigation use. Much of the northern part of the basin near the Columbia River has no (or poorly developed) surface drainage because of highly permeable soil. Surface runoff has occasionally been observed from Sand Hollow. This runoff fills depressions about 2 miles south of UMDA, from which the water infiltrates into the gravels[11].

1.2.2.1.5 Ground Water Use, Artificial Recharge ,and Water Balance. An estimated ground water balance (an accounting of gains to and losses from the ground water system) has not been reported for the entire Umatilla Basin. However, Miller[11] provides information that makes possible an estimate of the ground water balance of the Ordnance Critical Ground Water Area (referred to below as the Ordnance Area), a 35-square-mile area that adjoins UMDA on the east and south. The Ordnance Area contains an unusually productive unconfined aquifer that has been tapped for irrigation. Additional information that supports an estimated natural recharge rate of approximately 0.5 inch per year (in./yr) is supplied by Bauer and Vaccaro[14]. The water balance primarily reflects the alluvium, though some pumping occurs from basalt aquifers. The water balance is dominated by artificial effects, as discussed below.

The water balance for the Ordnance Area is summarized in the following list, which reflects conditions from 1978 to 1984:

- Recharge to ground water

- Precipitation/infiltration	1,000 acre-feet per year (af/yr)
- Stream seepage	Unknown
- Canal leakage	11,000 af/yr
- Inflow from west	2,000 af/yr
- Artificial recharge (mean)	5,400 af/yr

- Discharge from ground water

- Springs/seepage to Umatilla River	2,000 af/yr
- Ground water outflow	Unknown
- Direct evapotranspiration	Small
- Pumping	18,600 af/yr

Recharge to Ground Water. Ground water recharge from precipitation in the vicinity of UMDA is estimated to be approximately 0.5 in/yr or less[14]. In the area immediately to the southeast of UMDA, however, recharge rates of approximately 2 to 5 in/yr are estimated due to irrigation activities.

Seepage from the Umatilla River probably occurs when its level is high, but the rate is unknown. Leakage from canals east of UMDA is fairly accurately measured at 11,000 af/yr. Leakage from canals south of UMDA is probably much less because of less permeable soil.

An area of 29,780 irrigated acres west of the Ordnance Area is irrigated by water from the Columbia River. In the past, excess irrigation water may have recharged ground water in this area at a fast enough rate to cause northeastward flow into UMDA from off post.

An artificial recharge canal 1 mile south of UMDA is operated by the County Line Water Improvement District. It consists of 2.5 miles of unlined canal, 15 feet wide, that is supplied with water from the High Line Canal, which obtains water from Butter Creek. Recharge from the canal began in 1977, with recharge of 469 acre-feet of water. Between 1978 and 1984, annual recharge ranged from 3,149 to 6,763 af/yr, with a mean of 5,358 af/yr. Ground water levels south of UMDA have increased approximately 12 feet since 1977, and at least half of this increase is attributed to the artificial recharge canal[10].

Discharge from Ground Water. Springs occur along the Umatilla River near the northeast corner of the Ordnance Area. Their discharge, though estimated, increases markedly during the irrigation season because of leakage from nearby canals.

Ground water flows out of the Ordnance Area in the subsurface, but information on gradients and flow direction is too sparse to estimate its flow rate.

Evapotranspiration directly by plants whose roots reach the saturated zone is probably slight, because in most parts of the area the depth to ground water appears to be several tens of feet.

Pumping largely for irrigation, is the major discharger of ground water. Total pumpage (18,600 af/yr) has been relatively stable since 1971.

1.2.2.1.6 Meteorology. The following meteorological information is compiled from data from Gale Research Company and U.S. Environmental Data Service[15].

UMDA is located within the northern portion of the Columbia Basin, which enjoys a relatively mild climate. The temperature ranges from 24° to 90°F, with a mean annual temperature of 52.6°F. Normal daily average temperatures vary from 35°F in January to 70°F in July. The mild temperatures are a result of the moderating effect of the Pacific Ocean to the west.

The majority of the moisture picked up from the Pacific Ocean falls on the western slopes of the Pacific Coast Range and the Cascades as the air mass moves eastward. Precipitation in the Hermiston area is relatively low, with an annual mean of 8.87 inches. Only about 10 percent of the annual precipitation falls in summer. For the month of January, the mean total precipitation is 1.91 inches; during July, the mean total is only 0.23 inch. The area receives an average of 9.8 inches of snow annually.

Mean relative humidity varies from 80 percent in January to only 35 percent in July. The humidity tends to be approximately 5 percent higher in the morning throughout the year. Consistent with the low summer humidity, 80 to 90 percent annual evaporation occurs between May and September.

1.2.2.2 Individual Site Descriptions

1.2.2.2.1 Site 3 - Hazardous Waste Storage Facility (Building 203). The Hazardous Waste Storage Facility is housed in Building 203, a large structure of wood-frame construction with a metal roof and siding and a concrete floor. Hazardous wastes are stored in a small fenced area within the building and are surrounded by a 6-inch-high concrete berm to contain any spills. Baghouse dust, battery acid, and used oil were stored in this area during the August 1989 site visit by Dames & Moore. In addition, PCB transformers were temporarily stored in Building 203; they were covered with plastic bags and located in a bermed area adjacent to the fenced-in storage area. The entire storage area was clean and well maintained, and the concrete floor appeared to be structurally sound.

A former UMDA employee indicated that in the early 1970s drums containing Agent Orange were stored in Building 203 and leaked onto the concrete floor. The spilled

material was reportedly washed out of the building onto the soil near the northern doors of the building. None of the other retirees recalled the storage or leaking of Agent Orange.

1.2.2.2.2 Site 6 - Sewage Treatment Plant. The Sewage Treatment Plant treats the domestic wastewater generated in the administration area via a Parshall flume, two Imhoff tanks, a sludge-drying bed, and a tile field percolation system that drains to a sand/gravel filter. One of the Imhoff tanks has been inactive for the past 10 to 20 years because of the low demand for sewage treatment at the Depot. Previous sampling by Battelle is believed to have taken place in the tile field, which revealed the presence of DDT in the subsurface soil. The Sewage Treatment Plant tile field does not receive water from the administration area storm sewer system.

1.2.2.2.3 Site 9 - Remote Munitions Disassembly. This area (also known as the TV Remote Site) was used primarily to disassemble conventional munitions (including very large bombs). It may have also occasionally been used to drain and disassemble bombs containing GB/VX nerve agents. The area is no longer in use. A surface soil sample collected and analyzed by Battelle in 1981 revealed no isopropyl methyl phosponate (IMPA), a degradation product of agent GB.

1.2.2.2.4 Site 10 - Former Agent H Storage Area. The Former Agent H Storage Area is a strip of ground formerly used to store 1-ton containers of mustard agent. Some containers reportedly leaked mustard agent onto the gravel and soil in this area. Reportedly, such leaks and spills were cleaned up and decontaminated immediately, and the residues were buried nearby, possibly in an angular-shaped pit located approximately 300 feet south of the former storage area. The 1981 sampling of surface and subsurface soil by Battelle did not detect the mustard agent degradation product thiodiglycol.

1.2.2.2.5 Site 22 - Defense Re-utilization Marketing Office (DRMO). The DRMO Area is located in the southwest portion of the UMDA administration area. The site is used to store scrap and salvage materials, including metals, wooden crates, waste oils, and old transformers, as well as scrap metal, empty shells and cartridges, vehicles and furniture. These materials are stored in a warehouse building or outside on a paved area or bare ground while awaiting sale or off-site disposal. A former UMDA employee reported that leaking transformers had been stored on bare ground in a shed at the site.

1.2.2.2.6 Site 25(I) - Metal Ore Piles-Location I. One metal ore pile is currently located to the southeast of Building 200, in the southwestern portion of UMDA. This pile may have been at its present location since the latter days of World War II. Historic aerial photographs indicate that an additional pile had been located west of the existing pile. Presently, the ore pile is not covered and is located directly on bare ground. A previous sampling investigation revealed elevated lead concentrations in the soil at this location.

1.2.2.2.7 Site 25 (II) - Metal Ore Piles-Location II. Three metal ore piles are currently located south of K Block in the north-central portion of UMDA. These piles may have been at their present locations since the latter days of World War II. Historical aerial photographs indicate that an additional pile had been located west of the existing piles. Presently the ore piles are not covered and are located directly on bare ground. A soil sample collected from this location by a previous investigation had total metals concentrations below or equal to UMDA background soil concentrations.

1.2.2.2.8 Site 26 - Metal Ingot Stockpiles. This site, located east of Building 200, consists of 6-foot high stacks of lead and zinc ingots. It occupies a total area of 30,000 to 40,000 square feet. The piles rest directly on gravelly soil. In addition, the aluminum ingots were reportedly once stored in the southern part of the site.

1.2.2.2.9 Site 27 - Pesticides Storage Building. The Pesticide Storage Building in the central portion of the UMDA administration area is used to store a limited supply of unspecified pesticides. The pesticides are kept in two bermed rooms with concrete floors. A 250-gallon aboveground storage tank located outside the building is reportedly used to collect liquids from a sink drain. The sink is used to clean materials that have come in contact with pesticides. Previously, the building was also used to store paints and solvents.

1.2.2.2.10 Site 29 - Septic Tanks. Sixteen active (including two at the Sewage Treatment Plant) and seven inactive Septic Tanks are located throughout UMDA. (Refer to Plate 1 of the RA for details on the specific locations of these tanks.) Five of the tanks were sampled by Weston in 1988, because they were suspected of containing contaminants from the buildings they service. Four of the five tanks sampled were found to contain significant concentrations of inorganic contaminants, and one contained RDX. A former septic tank/field in the ADA area is also of potential concern because of reports of possible disposal of GB/VX decontamination solutions. Another septic tank and associated leach field in the central portion of the Depot may also be contaminated from the reported disposal of battery acid. All other septic tanks were apparently used for human wastes or nonhazardous materials only.

1.2.2.2.11 Site 30 - Storm Water Discharge Area. Storm water collected in storm sewers located in the administration area discharges to a small ditch at this site. There was no evidence of any environmental degradation in this area during the 1989 site visit. Earlier reports incorrectly identified this discharge area at the location of the Sewage Treatment Plant tile field (Site 6), which is actually located several hundred feet to the northeast.

1.2.2.2.12 Site 33 - Gravel Pit Disposal Area. It is reported that this gravel pit may have been used to dispose of GB/VX decontamination solutions. Some crushed drums and various metals debris were observed at the site during Dames & Moore's 1989 site visit. White crystals were noted by the former employee who reported, but did not actually witness, the disposal incident. The white crystals were evident for approximately 1

year after the disposal incident, which reportedly took place in the late 1960s. No white crystals were observed at this site during the 1989 site visit; however, similar-looking naturally occurring calcium deposits were noted by Dames & Moore in a number of other areas at UMDA.

1.2.2.2.13 Site 34 - Paint Spray and Shot Blast Areas. Portable shot blast machine and open-air spray paint operations were conducted at Areas 2000 and 2001. The residues from these operations were reportedly disposed of on surrounding soils. Area 2001 was also used as a propellant transfer and storage location.

1.2.2.2.14 Site 35 - Malathion Storage Leak Area. A shipment of leaking insecticide containers was received at UMDA in the late 1970s and reportedly stored on the gravel to the north of Building 108. The relocation and ultimate disposition of the pesticides are uncertain; however, a former UMDA employee noted that the pesticides may have been burned at the ADA grounds or transferred to new containers and sold.

1.2.2.2.15 Site 36 - Building 493 Paint Sludge Discharge Area. Paint spray booths used in Building 493 near the Explosive Washout Plant reportedly discharged paint sludge, solvents, and possibly other wastes into the coulee northwest of the building via an underground drainage system. In addition, a brass cleaning solution containing cyanide was reportedly disposed of in this drainage system. Abundant paint stains were observed on soil near the two pipe discharge locations located along the coulee.

1.2.2.2.16 Site 37 - Building 131 Paint Sludge Discharge Area. A depression to the west of Building 131 was reportedly used to collect paint sludges and solvents generated from paint spray operations in Building 131. A wooden and metal conduit jutting from the subsurface to the west of the building into the depression was observed in this area during the 1989 site visit. Abundant paint residue was observed on site soil.

1.2.2.2.17 Site 39 - QA Function Range. The Quality Assurance (QA) Function Range is located in the northeast corner of UMDA. The area was used for two separate operations. The central portion of the site, west of Coyote Coulee, served as a rifle and pistol range. The southern portion of the site, east of the coulee, served as a QA testing area for flares, photoflash grenades, and mines. At the rifle range, a disposal area for metal banding material was noted along the coulee during the 1989 Dames & Moore site visit. According to aerial photographs and interviews with current and former Depot employees, the QA testing area was active from the late 1940s through the 1960s, and the rifle range was in use from the late 1940s through the mid-1970s.

1.2.2.2.18 Site 44 (I) - Road Oil Application Site-Location I. This part of Site 44 is located in the southwest portion of UMDA. Location I was identified during review of historic aerial photographs. Hardened road oil material, covering approximately 100 square feet, was observed in this area during the 1989 site visit.

1.2.2.2.19 Site 44 (II) - Road Application Sites-Location II. This part of Site 44 is located in the south-central portion of the Depot, to the south of the DRMO. Review of historical aerial photographs and interviews with former UMDA employees indicate that road oil was disposed of in this area from the mid-1950s through the mid 1960s to limit dust emissions. In addition, the southern portion of this area was used during the same period to transfer road oil from commercial supply trucks to Army supply vehicles. Furthermore, the eastern section of the area was used in the late 1940s to store drums of road oil and tar and to change the oil in Army vehicles. The waste oil was reportedly drained directly onto the soil. Presently, this area appears to be covered with a thin layer of macadam overlain with a thin soil cover. During the Dames & Moore site visit, there were some small areas where a tar-like substance was noted, and vegetation was growing through portions of the asphalt.

1.2.2.2.20 Site 45 - Building 612 and Building 617 Boiler. Buildings 612 and 617 are boiler house buildings located in the northwestern portion of the Depot. At both of these sites, boiler blowdown effluent discharges to nearby soil. A lack of vegetation was noted in both of these areas. Dark staining of the soil was noted at the discharge location associated with Building 612.

1.2.2.2.21 Site 46 - Railcar Unloading Area. This area is located in the southwest portion of the Depot. Historical aerial photographs indicate that coal or ore was stored in this area from approximately 1949 or earlier through the late 1950s or early 1960s. Former UMDA employees noted that this area was also used as an unloading area for brass bullets in the late 1960s and early 1970s. The soil surrounding the concrete pad at this site was noted to be significantly littered with brass and metal debris during the 1989 Dames & Moore site visit.

1.2.2.2.22 Site 47 - Boiler/Laundry Effluent Discharge Site. This site is located in the central portion of the Depot. To the south of the boiler plant building is a metal trough that was formerly used to discharge effluent during blowdown of the boilers. The laundering of clothes contaminated with explosives also took place in the boiler plant building, and effluent from the laundry operations was discharged to the metal trough, the effluent was discharged into a rock-lined pit approximately 25 feet in diameter and 8 to 10 feet deep.

1.2.2.2.23 Site 48 - Pipe Discharge Area. Located in the south-central portion of the Depot is a pipe approximately 8 inches in diameter and 15 feet in length that discharges into a long ravine approximately 25 feet deep. A rusted 55-gallon drum was noted in the ravine during the 1989 Dames & Moore site visit. A sweet odor was reportedly detected near the drum, indicating the possible presence of pesticides. UMDA employees determined that this discharge pipe is connected to the large Imhoff tank associated with the Sewage Treatment Plant (Site 6) several hundred feet east of the site. Current UMDA employees indicate that this discharge area has not been used since the early 1970s.

1.2.2.2.24 Site 49 - Drill and Transfer (DAT) Area. Site 49 was located to the northwest of K Block. It was part of a 1984 program directed by USATHAMA to dispose of leaking chemical munitions. The site was approximately 3 acres in size and was divided into two halves separated by an earthen berm. The western half of the DAT site consisted of a personnel support station. The eastern half consisted of the "hot zone," where munitions were drilled, emptied, and decontaminated. The chemical agents were placed in holding tanks; the munitions castings were rinsed and monitored in decontamination tanks until concentrations of chemical agents were below prescribed levels, and then removed and disposed of. Site operations were reportedly conducted on the unprotected soil surface. One spill reportedly occurred during the operational period. The spilled product was treated as a chemical agent, and the situation was handled according to USATHAMA standard operating procedures (SOPs). The results of soil sample analyses conducted by the Pine Bluff Field Laboratory as part of closedown operations are unavailable. UMDA personnel reported that no soil was excavated as a result of the DAT operation.

1.2.2.2.25 Site 50 - Railroad Landfill Areas. The Railroad Landfill Areas are located in the south-central portion of UMDA, approximately 500 feet south and southeast of the Sewage Treatment Plant. The site consists of two landfills: one located north of the railroad tracks, with dimensions of approximately 30 by 100 feet, and another located south of the railroad classification yard, with dimensions of 30 by 400 feet. The fill area to the south of the railroad yard is laterally discontinuous. Fill depths are unknown. both of these landfills consist of topographic depressions formed when the railroad grade was installed and gradually filled in with debris. Based on field reconnaissance and observed rusted metal debris at the surface, disposal north of the railroad yard is limited to metal scrap materials. A former UMDA employee suggested that railroad cars may have been cleaned out and resulting debris disposed of at this location. The landfill south of the railroad tracks was described by a former UMDA employee as a "dry" landfill in which construction rubble was disposed. Abundant concrete fragments were visible in this area during the 1989 site visit.

1.2.2.2.26 Site 52 - Coyote Coulee Discharge Gullies. Three erosional gullies were observed along Coyote Coulee near the Explosive Washout Plant (Building 489), both in the historical and aerial photographs and during the site reconnaissance. The flume leading to the washout lagoons and the paint discharge areas/gullies associated with Building 493 are described separately (see Site 5 and Site 36 descriptions) and are not considered a part of Site 52. The three gullies range from a few inches to a few feet in depth, are of varying widths, and generally exhibit stressed vegetation. Because precipitation is so sparse at UMDA, the gullies are presumed to be the result of liquid discharges into areas along Coyote Coulee from the various operations in the washout plant area. This was confirmed by former UMDA employees.

One gully originates from the top of the coulee near the northern end of Building 489. Reportedly, this gully was used to discharge washout plant effluents before the washout lagoons (Site 4) were constructed in the early 1950s. A second gully originates at the top

of the coulee near a concrete pad, which was formerly a building site north of Building 489. A third gully originates to the south of Building 489 along the coulee, near what was identified by former UMDA employees as an ammunition disassembly structure. These gullies were noted in the earlier available aerial photograph (1949) and do not appear to have revegetated significantly in more recent years; thus, they were probably in use throughout many of the active years for the washout plant area operations (mid-1950s through 1965).

1.2.2.2.27 Site 53 - Building 433 Collection Sump/Cistern and Disposal. An underground sump or cistern is located approximately 40 feet to the south of Building 433, across the railroad tracks. The sump/cistern is apparently constructed of concrete and includes a 4-inch diameter stand pipe in the center of a 3- by 3-foot concrete pad. Fluid was observed in the sump/cistern approximately 9 feet below the ground surface. This sump is apparently used to collect boiler blowdown fluids from Building 433.

An area of stained soil approximately 10 by 20 feet in size was observed approximately 40 feet to the north of Building 433, just north of a fenced transformer area. This area had recently been reworked as evidenced by bulldozer tracks. The soil surface was covered with a dark grey, oily substance.

1.2.2.2.28 Site 67 - Building 493 Brass Cleaning Operations Area. This site is located south of Building 493 in the east-central part of UMDA. Site 67 was discovered through interviews with former UMDA employees. In the late 1960s, brass shells were cleaned with cyanide-containing "WEDAC" solution on concrete pads south of Building 493. Former UMDA employees suspect that the WEDAC solution may have been spilled on soil adjacent to the concrete pads. Prior to the late 1960s, the cleaning operations were conducted inside Building 493, and the waste liquid was disposed of in the paint spray booth drains (Site 36).

1.2.2.2.29 Site 80 - Disposal Pit and Graded Area. Site 80 is located between Eleventh Street and the ADA boundary, just south of Site 21 (Missile Fuel Storage Area). The site was discovered through review of historical aerial photographs. The eastern part of the site once included a trench or pit, and the rest of the site included graded areas. The only remaining evidence of this site observed during the January 1990 site visit was a slight depression in the location of the former trench. Pieces of broken concrete were present in the depression. There are no records of disposal operations at Site 80, nor did interviews with former UMDA employees reveal any information regarding this site.

1.2.2.2.30 - Site 81 (I) - Former Raw Materials Storage Site - Location I. Location I is in the southwestern warehouse area of UMDA. This site was discovered through review of historical aerial photographs. Piles of raw materials were stored in direct contact with the ground at Location I during the 1940s and 1950s. Little evidence of this former storage location was seen during the January 1990 site visit, though some of the area has not revegetated. Interviews with former UMDA employees did not reveal the type(s) of materials stored here.

1.2.2.2.31 Site 81 (II) - Former Raw Materials Storage - Location II. Location II is at the southeast corner of Igloo Block H. This site was discovered through review of historical aerial photographs. Piles of raw materials were stored in direct contact with the ground at these locations during the 1940s and 1950s. Little evidence of these former storage locations was seen during the January 1990 site visit, though some of the areas have not revegetated. Interviews with former UMDA employees did not reveal the type(s) of materials stored here.

1.2.2.3.32 Site 82 - Former Gravel Pit/Disposal Location. Site 82 is located in the west-central part of UMDA, at the southeast corner of Igloo Block I. This site was historically a gravel pit. However, during the January 1990 site visit, pieces of what appeared to be asbestos-containing transite siding were observed at the surface in two places on the pit floor. There are no records of disposal operations at this site, nor do former UMDA employees interviewed recall any disposal activities in this area.

1.2.3 Nature and Extent of Contamination

The following discussion summarizes the nature and extent of contamination at the Miscellaneous Sites. This summary is based on data and information developed in the RI and supplemented by the RA and describes the occurrence of possible contaminants detected in concentrations exceeding background (comparison criteria) or Certified Reporting Limits (CRL) if the contaminant is not naturally occurring. Further detailed information regarding specific contaminants and levels and extent of contamination is provided in Section 1.2.5, Human Health Baseline Risk Assessment of this FS report.

At each site, it was determined that the primary route of migration of contaminants in soil was through windblown dust. At all the Miscellaneous Sites, very few ground water samples were analyzed because the low levels of contamination in the soils made it unlikely that ground water would be affected by soil contamination.

1.2.3.1 Site 3 - Hazardous Waste Storage Facility. Four surface soil samples were taken at this site. Four herbicides were detected but were not above the Certified Reporting Limits (CRLs).

1.2.3.2 Site 6 - Sewage Treatment Plant . Twenty-two subsurface soil samples were taken at six different locations within Site 6. Three to four samples, ranging in depth from 2.0 ft. to 10.0 ft., were taken at each location. Inorganic compounds exceeding the comparison criteria include: mercury (one sample, 2.5 ft.), nickel (one sample, 5.0 ft.), silver (six samples, 2.0, 2.5, 5.0, 10.0 ft.), zinc (one sample, 2.5 ft.), and nitrate/nitrite (four samples, 2.5, 5.0, 7.5, 10.0 ft.). Pesticide and PCB compounds exceeding the CRLs include: DDT (one sample, 2.5 ft.) and PCB 1260 (one sample, 2.5 ft.).

1.2.3.3 Site 9 - Remote Munitions Disassembly Area. Six surface samples were taken at this site and contaminants of concern were found in all of them. Inorganic compounds exceeding the comparison criteria include: antimony (six samples), cadmium (one sample), chromium (one sample), silver (two samples), and zinc (one sample). HMX and RDX exceeded the CRLs in one sample.

1.2.3.4 Site 10 - Former Agent H Storage Area. Seven surface and five subsurface (2.5, 5.0, 7.5, 10.0, 10.0 ft.) soil samples were taken at this site. Antimony exceeded the comparison criteria in four samples at depths of 0.0, 2.5, 5.0, and 10.0 feet. Chloroform exceeded CRLs in one sample at the surface. No other organic contaminants or breakdown products of mustard agent exceeded the CRLs.

1.2.3.5 Site 22 - Defense Reutilization Marketing Area. Eleven surface soil samples were taken at this site. Contaminants of concern were found at many of the eleven locations. Inorganic compounds exceeding the comparison criteria include: antimony (three samples), barium (one sample), cadmium (two samples), copper (five samples), lead (two samples), silver (eight samples), and zinc (nine samples). The organic compounds exceeding CRLs include: the pesticides DDD (three samples), DDE (six samples), and DDT (six samples), as well as total petroleum hydrocarbons (one sample).

1.2.3.6 Site 25(I) - Metal Ore Piles - Location I. Six surface soil samples were taken at this site. Thallium exceeded the comparison criteria in three of the six samples.

1.2.3.7 Site 25(II) - Metal Ore Piles - Location II . Ten surface soil samples were taken at this site. Inorganic compounds exceeding the comparison criteria include: nickel (three samples), and thallium (one sample).

1.2.3.8 Site 26 - Metal Ingot Stockpiles. Six surface soil samples were taken at this site. Inorganic compounds exceeding the comparison criteria include: lead (one sample) and zinc (four samples).

1.2.3.9 Site 27 - Pesticide Storage Building. Two surface soil samples were taken at this site. The pesticide DDT was just above the CRLs in two samples and zinc was above the comparison criteria in one sample. Organic compounds exceeding CRLs in one sample include: fluoranthene, phenanthrene, and pyrene.

1.2.3.10 Site 29 - Septic Tanks . Three sludge samples (0.0, 0.0, 3.0 ft.) and 51 subsurface soil samples ranging from 0.0 to 10.0 ft. were taken at this site. Inorganic compounds exceeding the comparison criteria include: calcium (one sample, 7.5 ft.), chromium (one sample, 2.5 ft.), manganese (one sample, 5.0 ft.), nickel (one sample, 2.5 ft.), silver (three samples, 2.5, 5.0, 7.5 ft.), sulfate (one sample, 3.0 ft.), sulfide

(two samples, 5.0, 7.5 ft.), and zinc (one sample, 2.5 ft.). Organic compounds exceeding CRLs include: trichloromethane (one sample, 2.5 ft.) and acetone (one sample, 0.0 ft.).

1.2.3.11 Site 30 - Storm Water Discharge Area. Two surface soil samples were taken at this site. Inorganic compounds exceeding the comparison criteria include: silver (two samples), and zinc (two samples). Pesticide compounds exceeding the CRLs include: DDD (two samples), DDE (two samples), and DDT (one sample). Oil & grease exceeded the CRLs in both samples.

1.2.3.12 Site 33 - Gravel Pit Disposal Area. One surface soil sample and four subsurface soil samples (2.5, 5.0, 7.5, 10.0 ft.) were taken at this site. The samples were analyzed for IMPA and EMPA, which are breakdown products of agents GB and VX. However, there was no detectable contamination in the soil at this site.

1.2.3.13 Site 34 - Paint Spray and Shot Blast Areas. Three surface soil samples were taken at this site. Inorganic compounds exceeding the comparison criteria include: chromium (one sample) and zinc (two samples). Organic compounds exceeding the CRLs include: di-n-butyl phthalate (one sample) and phenanthrene (one sample). Oil & grease and total petroleum hydrocarbons also exceeded the CRLs in one sample.

1.2.3.14 Site 35 - Malathion Storage Leak Area. Three surface soil samples and seven subsurface soil samples (2.0, 4.0 ft.) were taken at this site. The samples were analyzed for chlordane, DDE, DDT, and malathion only. The pesticide compounds exceeding the CRLs include: chlordane (one sample), DDE (five samples), and DDT (six samples). Malathion was not detected.

1.2.3.15 Site 36 - Building 493 Paint Sludge Discharge Area. Five surface soil samples were taken at this site. Inorganic compounds exceeding the comparison criteria include: cadmium (three samples), chromium (two samples), copper (one sample), iron (one sample), nickel (one sample), silver (two samples), zinc (three samples), and nitrate/nitrite (one sample).

1.2.3.16 Site 37 - Building 131 Paint Sludge Discharge Area. Four surface soil samples were taken at this site. Inorganic compounds exceeding the comparison criteria include: barium (one sample), cadmium (two samples), chromium (two samples), mercury (one sample), and zinc (three samples). Organic compounds exceeding the CRLs include: tetrachloroethylene (one sample) and bis (2-ethylhexyl) phthalate (two samples).

1.2.3.17 Site 39 - QA Function Range. Ten surface soil samples were taken at this site. Inorganic compounds exceeding the comparison criteria include: antimony (one sample), copper (three samples), lead (two samples), silver (two samples), and zinc (two samples).

1.2.3.18 Site 44(I) - Road Oil Application Site - Location I. Only one surface soil sample was taken at this site. The only organic compound which exceeded the CRL was oil & grease.

1.2.3.19 Site 44(II) - Road Oil Application Site - Location II . Seven surface soil samples were taken at this site. The only organic compound that exceeded the CRL was oil & grease in six samples.

1.2.3.20 Site 45 - Building 612 and Building 617 Boiler. Two surface soil samples were taken at this site. The samples were analyzed only for inorganics. The compounds that exceeded the comparison criteria include: copper (one sample), iron (one sample), nickel (two samples), silver (one sample), and zinc (two samples).

1.2.3.21 Site 46 - Railcar Unloading Area. Three surface soil samples were taken at this site. Inorganic compounds exceeding the comparison criteria include: copper (two samples), and zinc (three samples). Organic compounds exceeding the CRLs include: 2-methylnaphthalene (three samples), anthracene (one sample), di-n-butyl phthalate (two samples), dibenzofuran (three samples), fluoranthene (one sample), n-nitrosodiphenylamine (one sample), naphthalene (three samples), and pyrene (one sample).

1.2.3.22 Site 47 - Boiler/Laundry Effluent Discharge Site. Twenty-four soil samples from five different locations and two sludge samples from two different locations were collected at this site. The soil samples from two of the locations ranged in depth from 0.0 to 110.0 ft. and from 0.0 to 115.0 feet. The soil samples from the fourth and fifth locations ranged from 0.0 to 3.0 feet. The third location and the sludge samples were taken from the surface. Inorganic compounds exceeding the comparison criteria include: antimony (two samples), arsenic (one sample), barium (two samples), cadmium (three samples), calcium (two samples), chromium (two samples), cobalt (one sample), copper (three samples), iron (one sample), lead (three samples), magnesium (two samples), manganese (one sample), mercury (twelve samples), nickel (five samples), selenium (three samples), silver (five samples), sodium (two samples), vanadium (one sample), zinc (six samples), and nitrate/nitrite (four samples). Organic compounds exceeding the CRLs include: acetone (one sample), ethylbenzene (one sample), tetrachloroethylene (one sample), toluene (one sample), xylenes (one sample), 2-methylnaphthalene (one sample), acenaphthene (one sample), anthracene (two samples), benzo (a) anthracene (two samples), benzo (a) pyrene (one sample), benzo (b) fluoranthene (four samples), benzo (g,h,i)perylene (one sample), benzo (k) fluoranthene (four samples), chrysene (six samples), fluoranthene (five samples), fluorene (one sample), ideno (1,2,3-c,d) pyrene (one sample), phenanthrene (five samples), and pyrene (six samples). Pesticide (PCB) compounds exceeding the CRLs include: chlordane (one sample), DDD (three samples), DDE (four samples), DDT (five samples), and PCB-1260 (one sample).

1.2.3.23 Site 48 - Storm Water Discharge Area. Three surface soil samples were taken at this site. Inorganic compounds exceeding the comparison criteria include: cadmium (one sample), copper (one sample), mercury (two samples), silver (three samples), zinc (three samples), and nitrate/nitrite (two samples). Pesticide compounds exceeding the CRLs include: DDD (three samples), DDE (two samples), and DDT (two samples).

1.2.3.24 Site 49 - Drill and Transfer Area. Four surface soil samples were taken at this site. The samples were analyzed for IMPA and EMPA only because these are breakdown products of chemical agents GB and VX. No contaminants were detected.

1.2.3.25 Site 50 - Railroad Landfill Areas. Six subsurface soil samples (2.5, 6.5, 10.0 ft.) were taken at this site. The only inorganic compound which exceeded the comparison criteria was zinc in one sample. Oil & grease exceeded the CRLs in five of the six samples.

1.2.3.26 Site 52 - Coyote Coulee Discharge Gullies. Eight surface soil samples were taken at this site. Inorganic compounds exceeding the comparison criteria include: copper (one sample) and zinc (three samples). Explosives HMX and RDX both exceeded the CRLs in one sample.

1.2.3.27 Site 53 - Building 433 Collection Sump/Cistern and Disposal. One surface soil sample was taken at this site. Inorganic compounds exceeding the comparison criteria include both nickel and potassium. Organic compounds exceeding the CRLs include: anthracene, phenanthrene, and pyrene. In addition, oil & grease exceeded the CRL.

1.2.3.28 Site 67 - Building 493 Brass Cleaning Operations Area. One surface soil sample and seven subsurface soil samples (2.0, 4.0, 6.0, 8.0, 40.0, 89.0, 129.0 ft.) were collected at this site. Inorganic compounds exceeding the comparison criteria include: calcium (one sample, 129.0 ft.) and silver (one sample, 8.0 ft.). There were no organic contaminants of concern.

1.2.3.29 Site 80 - Disposal Pit and Graded Area. Four subsurface soil samples (2.5, 5.0, 7.5, 10.0 ft.) were taken at this site. There were no contaminants of concern found at this site.

1.2.3.30 Site 81(I) - Former Raw Materials Storage Site - Location I. Four surface soil samples were collected at this site. There were no contaminants of concern found.

1.2.3.31 Site 81(II) - Former Raw Materials Storage Site - Location II. Two surface soil samples were taken at this site. The samples were analyzed for inorganic contaminants only. No contaminants of concern were found.

1.2.3.32 Site 82 - Former Gravel Pit/Disposal Location. Two surface soil samples and three subsurface soil samples (2.5, 10.0, 10.0 ft.) were taken at this site. In one sample asbestos (chrysolite) was detected at the surface, and chloroform exceeded the CRL in one sample at 10.0 feet deep.

1.2.4 Contaminant Fate and Transport

The exposure to humans and the environment imposed by the contaminants of concern identified at UMDA is influenced by a number of factors. These factors include the interrelated characteristics of the contaminants such as physical and chemical properties and environmental fate and transport parameters. Fate and transport profiles for each of the contaminants of concern at UMDA are presented in Appendix C of the RA[4]. Physical and chemical characteristics and environmental fate parameters for organic and inorganic contaminants of concern at UMDA are summarized in Tables A-1 and A-2 in Appendix A of this FS. Note that Appendix A has been extracted from the RA; full reference citations are provided in the RA[4].

The primary factors that affect the fate and transport of contaminants of concern in soil at the Miscellaneous Sites Operable Unit include: photolysis, sorption (absorption and adsorption) to soil, and bioaccumulation. To a more limited extent, biotransformation and biodegradation may impact the fate and transport of the organic contaminants of concern. Mobility of the contaminants through soil to ground water is not a particular concern at the Miscellaneous Sites due to the relative immobility of the contaminants of concern as well as the depth to ground water (in excess of 50 feet).

In general, the metals found at the Miscellaneous Sites are relatively immobile in soil. This immobility is affected by the insolubility of the metals in water as well as the sorption of some metals to soil particles. The metals are generally present in nonvolatile forms and are nondegradable, both characteristics that will limit the potential for natural restoration of the soil. Many of the metals found at the Miscellaneous Sites will bioaccumulate and therefore impact specific human and environmental exposure routes.

The fate and transport of explosive contaminants of concern at the Miscellaneous Sites are primarily affected by photolysis and sorption. Although the explosives are generally resistant to biodegradation, degradation has been observed under optimum conditions. In general, the explosive contaminants are nonvolatile and are insoluble in water.

Sorption of pesticide contaminants of concern to soil is an important factor in the environmental fate and transport of these compounds. In dry soils, volatility of the pesticides is not a significant factor in their transport. The pesticides are relatively insoluble in water.

1.2.5 Human Health Baseline Risk Assessment

This section of the FS summarizes the results of the Human Health Baseline Risk Assessment of the Miscellaneous Sites Operable Unit as presented in the RA. For a detailed presentation of the results, refer to the RA.

1.2.5.1 Selection of Contaminants of Concern. The data used in the development of the RA are from the Weston[16] and/or Dames & Moore (1990-1992) remedial investigations. These particular data were selected because they better represent current site conditions and because sample collection and analysis were conducted using USATHAMA protocols. The potential contaminants of concern from those investigations were those that met one or more of the following criteria:

- Positive detection in at least one sample in at least one medium
- Significant elevation above method blanks (5 to 10 times the method blank concentration depending on the compound)
- Inorganic compounds present at concentrations above the maximum background sample concentration
- Tentatively Identified Compounds (TICs) if known to be site related
- Identified as transformation products of other contaminants of concern

Contaminants identified in ground water and soil based on the above criteria for the Miscellaneous Sites are summarized in Table 1-1 and Table 1-2, respectively. Only a limited number of the Miscellaneous Sites had any ground water sampling completed during the RA. For reference, background concentrations of the contaminants are included (if available or appropriate) in these tables.

In identifying contaminants in soil, it was assumed that soil at depths greater than 10 feet would not be available for exposure; therefore, only soils collected from 10 feet or shallower were included in this analysis.

From the information presented in Tables 1-1 and 1-2, the following is observed:

- Of the sites for which ground water was sampled, only Sites 47 and 67 contain contaminants of concern (Site 4, also listed in Table 1-1, is addressed in a separate Operable Unit - OU3).

- Only the sites that contain contaminants of concern in the soils are listed in Table 1-2. This reflects the fact that Sites 3, 6, 10, 25II, 27, 29, 30, 33, 34, 35, 39, 44I, 44II, 45, 46, 49, 53, 80, 81I, 81II, and 82 do not contain contaminants of concern.

Note that the contaminants presented in Tables 1-1 and 1-2 reflect only those contaminants that are classified as contaminants of concern based on the above criteria. Subsequent assessments to determine and identify contaminants that contribute to unacceptable risk are summarized on a site-by-site basis in Section 2.3.2, Estimated Areas and Volumes of Contaminated Media Requiring Remediation.

1.2.5.2 Toxicity Assessment. The purpose of the toxicity assessment is to qualitatively and quantitatively assess the toxicological hazards of the contaminants of concern as a function of the anticipated route of exposure (e.g., ingestion or inhalation).

Table 1-1. Summary of Contaminants of Concern in Ground Water

Site	Contaminant of Concern	95% UCL Concentration ug/l	Frequency of Detection	Background Concentration ug/l (a)
47, 67	Antimony	2.9	2 of 13	1
(Alluvial	Arsenic	15	13 of 13	1
Aquifer)	Chromium	11	6 of 13	1
	Copper	7.16	3 of 13	1
	Lead	5.84	6 of 13	5
	135TNB	47.1	17 of 89	
	246TNT	418	12 of 89	
	24DNT	49.8	9 of 89	
	HMX	160	14 of 89	
	RDX	729	52 of 89	
47, 67	Antimony	3.57(b)	1 of 1	1
(Confined	135 TNB	14.5	2 of 8	
Aquifer)	246 TNT	142	4 of 8	
	24DNT	22	2 of 8	
	HMX	128	4 of 8	
	RDX	1900	4 of 8	

UCL - Upper Confidence Limit

(a) - Background concentration as established in RI

(b) - Concentration detected in single sample

Source: Reference 4

Table 1-2. Summary of Contaminants of Concern in Soil

Site	Contaminant of Concern	95% UCL Concentration to 2-foot depth ug/g	Frequency of Detection	95% UCL Concentration to 10-foot depth ug/g	Frequency of Detection	Background Concentration ug/g (a)
9	Antimony	13.6	6/6			3.8
	Cadmium	4.21	1/6			3.05
	Lead	78	6/6			8.37
	Silver	0.053	6/6			0.038
	Zinc	229	6/6			94
	HMX	1.43	1/6			NSA
	RDX	0.69	1/6			NSA
22	Antimony	85.5	3/11			3.8
	Cadmium	26.1	3/11			3.05
	Copper	2045	5/11			58.6
	Lead	2668	11/11			8.37
	Silver	0.332	9/11			0.038
	Zinc	1286	11/11			94
	DDD	0.103	3/11			NSA
	DDE	0.128	6/11			NSA
	DDT	0.353	6/11			NSA
25I	Lead	8.39	6/6			8.37
	Thallium	35.3	3/6			31.3
25II	None					
26	Lead	42.3(b)	2/2			8.37
	Zinc	230(b)	2/2			94
36	Cadmium	478	3/5			3.05
	Chromium (d)	127	2/5			32.7
	Cobalt	18.6	1/5			15
	Copper	99.3	1/5			58.6
	Iron	29396	5/5			26233
	Lead	199	5/5			8.37
	Nickel	32.2	1/5			12.6
	Silver	0.23	2/5			0.038
	Zinc	6530	5/5			94
37	Barium	303	4/4			233
	Cadmium	5.87	2/4			3.05
	Chromium (d)	124	2/4			32.7
	Lead	355	4/4			8.37
	Mercury	0.327	2/4			0.056
	Zinc	233(b)	3/4			94
47	Antimony	142	1/7	68	1/14	3.8
	Barium	420	7/7	258	14/14	233
	Cadmium	21.5	1/7	10.9	1/14	3.05
	Calcium	66512	7/7	34457	14/14	29006
	Chromium (d)	36.9	1/7			32.7
	Copper	240	1/7	128	1/14	58.6
	Lead	401	7/7	193	14/14	8.37
	Magnesium	14825	7/7	9299	14/14	8585
	Mercury	0.533	6/7	0.338	8/14	0.056
47	Nickel	44.4	2/7	24.7	2/14	12.6
	Selenium	0.282	2/7			0.25

Table 1-2. Summary of Contaminants of Concern in Soil (continued)

Site	Contaminant of Concern	95% UCL Concentration to 2-foot depth ug/g	Frequency of Detection		95% UCL Concentration to 10-foot depth ug/g	Frequency of Detection		Background Concentration ug/g (a)
	Silver	0.449	2/7		0.219	2/14		0.038
	Zinc	895	5/7		449	9/14		94
	Benzo[A]Anthracene	0.249(b)	1/7		0.249(a)	1/14		NSA
	Benzo[B]Fluoranthene	0.449(b)	2/7		0.449(a)	1/14		NSA
	Benzo[K]Fluoranthene	0.23(b)	2/7		0.23(a)	2/14		NSA
	Chrysene	0.481(b)	2/7		0.481(a)	3/14		NSA
	Di-n-ButylPhthalate	0.813	1/7		0.421	1/14		NSA
	Fluoranthene	0.294(b)	2/7		0.294(a)	3/14		NSA
	Phenanthrene	0.093(b)	2/7		0.093(a)	2/14		NSA
	Pyrene	0.325(b)	2/7		0.249	3/14		NSA
	Chlordane	0.303	1/7		0.147	1/14		NSA
	DDD	0.109	1/7		0.054	1/14		NSA
	DDE	0.008	2/7		0.006	2/14		NSA
	DDT	0.057	2/7		0.03	2/14		NSA
	PCB-1260	0.319	1/7		0.171	1/14		NSA
	Nitrite/nitrate	18.6	5/7		10.3	10/14		9.9
48	Cadmium	6.47(b)	1/3					3.05
	Copper	118(b)	1/3					58.6
	Lead	68.6(b)	3/3					8.37
	Mercury	0.85(b)	2/3					0.056
	Silver	2.8(b)	3/3					0.038
	Zinc	467(b)	3/3					94
	DDD	7.4(b)	3/3					NSA
	DDE	1.94(b)	2/3					NSA
	DDT	1.16(b)	2/3					NSA
	Nitrite/nitrate	20(b)	3/3					9.9
50	Arsenic	5.51	4/5					1
	Copper	7.42	2/5					1
	Cyanide	12.1	1/5					NSA
	Nickel	53.8	2/5					NSA
	Vanadium	30.9(b)	4/4					NSA
	Zinc	523	2/5					74
	RDX	2.55						NSA
52	Copper	123	1/8					58.6
	Lead	15.7	8/8					8.37
	Zinc	136	8/8					94
	HMX	0.582	1/8					NSA
	RDX	0.864	1/8					NSA
67	Lead	43(c)	1/1		28.7	5/5		8.37
	Silver				0.044	3/5		0.038

UCL - Upper Confidence Limit
NSA - No Standard Available
(a) Background concentration as established in RI
(b) Maximum detected concentration (if it exceeds 95% UCL)
(c) Concentration detected in single sample
(d) Total chromium

Source: Reference 4

Toxicological profiles were developed as part of the RA and are included in the Appendix of that document. The profiles include the following information (when such information is available): noncarcinogenic effects and reference doses for oral ingestion and inhalation; carcinogenic effects, slope factors and weights-of-evidence for oral ingestion, dermal absorption, and inhalation; and references.

Quantitative toxicity data are presented in terms of reference doses and slope factors. Reference doses (RfD) values are used to evaluate noncarcinogenic effects. RfDs are derived from "no observed adverse effect levels" (NOAELs), which represent the highest experimental exposure level at which a particular critical toxic effect is not observed.

Cancer slope factors (SF) are used to evaluate potential human carcinogenic risks. An SF is defined as an estimate of the upper 95 percent confidence limit of the slope of the dose-response curve extrapolated to low doses, and is considered to be a measure of the cancer-causing potential of a chemical. RfDs and SFs are provided for both ingestion and inhalation exposure pathways.

Toxicity values used in the RA were obtained from the Integrated Risk Information System (IRIS), the Health Effects Assessment Summary Tables (HEAST), EPA Region III toxicity criteria, the Public Health Risk Evaluation Database, Drinking Water Criteria documents, Ambient Water Quality Criteria documents, Air Quality Criteria documents, and Agency for Toxic Substances and Disease Registry (ATSDR) toxicity profiles.

Toxicity values used in the RA are summarized in Table 1-3 for contaminants of concern identified in ground water and soil at the Miscellaneous Sites.

1.2.5.3 Exposure Assessment. The purpose of the exposure assessment is to: identify potential human and environmental receptors; identify and evaluate potential current and future exposure pathways; and determine the extent of exposure under site-specific current and future land use scenarios. The following 12 potential exposure pathways were identified for current and future receptors at UMDA as well as in the vicinity of the installation:

Pathway	Description
1	Dermal contact with contaminated soil
2	Inadvertent ingestion of contaminated soil
3	Inhalation of contaminated soil as airborne dust
4	Inhalation of vapors volatilized from soil
5	Ingestion of contaminated drinking water
6	Inhalation of volatile contaminants emitted from ground water during showering
7	Dermal contact with contaminated ground water during showering
8	Dermal contact of contaminated ground water during non-showering use

Table 1-3: Summary of Toxicity Criteria for the Contaminants of Concern

Chemical	RfDo (mg/kg/day)	RfDi (mg/kg/day)	SFo	SFi
TAL Inorganics				
Antimony	4.00E-04	ND	ND	ND
Arsenic	3.00E-04	UR	1.75E+00	1.40E+01
Barium	7.00E-02	1.40E-04	ND	ND
Cadmium	5.0E-04(b)	UR	ND	6.30E+00
Calcium	ND	ND	ND	ND
Chromium VI	5.00E-03	6.00E-07	ND	4.25E+01
Cobalt	1.00E-05	2.86E-04	ND	ND
Copper	3.70E-02	1.00E-02	ND	ND
Lead	IUBK Model	ID	ID	ID
Magnesium	ID	ID	ID	ID
Mercury (inorganic)	3.00E-04	9.00E-05	ND	ND
Nickel	2.0E-02(f)	UR	ND	8.4E-01(g)
Selenium	5.00E-03	ID	ID	ID
Silver	5.00E-03	ID	ID	ID
Thallium	8.0E-05(h)	ND	ID	ID
Vanadium	7.00E-03	ND	ND	ND
Zinc	2.0E-01(i)	ND	ND	ND
Cyanide (free)	2.00E-02	ND	ND	ND
1,3,5-Trinitrobenzene	5.00E-05	ND	ND	ND
2,4,6-TNT	5.00E-04	ND	3.00E-02	ND
2,4-DNT	2.00E-03	ND	6.80E-01	ND
HMX	5.00E-02	ND	ID	ND
RDX	3.00E-03	ND	1.10E-01	ND
Other Inorganics				
Nitrate(k)	1.60E+00	ND	ND	ND
Nitrite	1.00E-01	ND	ND	ND
TCL Semi-Volatiles				
Benzo(a) anthracene	ND	ND	5.80E+00	6.1E+00(n)
Benzo(b) fluoranthene	ND	ND	5.80E+00	6.1E+00(n)
Benzo(k) fluoranthene	ND	ND	5.80E+00	6.1E+00(n)
Chrysene	ND	ND	5.80E+00	6.1E+00(n)
Di-n-butyl phthalate	1.00E-01	ND	ND	ND
Fluoranthene	4.00E-02	ND	ND	ND
Phenanthrene	ND	ND	ND	ND
Pyrene	3.00E-02	ND	ND	ND
Pesticides/PCBs				
Chlordane	6.00E-05	UR	1.30E+00	1.30E+00
DDD	ND	ND	2.40E-01	ND
DDE	ND	ND	3.40E-01	ND
DDT	5.00E-04	ND	3.40E-01	3.40E-01
PCB 1260	ND	ND	7.70E+00	ND

ND - no data
ID - insufficient data available
UR - under review
RfDo - oral ingestion reference dose
RfDi - inhalation reference dose
SFo - oral ingestion slope factor
SFi - inhalation slope factor

Source: Reference 4

Note: Sources and references for the toxicity criteria presented are cited in Reference 4

Pathway	Description
9	Inhalation of vapors during non-showering use of ground water
10	Consumption of game that feeds on vegetation that grows in contaminated soil
11	Consumption of livestock (or their milk) that feed on vegetation growing in contaminated soil and/or that consume contaminated ground water
12	Consumption of crops irrigated by contaminated ground water and/or grown in contaminated soil

Pathways were reviewed for both current and future land use. Under current land use conditions, it was assumed that two receptors exist: UMDA employees and nearby residents.

Specific receptors identified for future land use are dependent on the selected use. Scenarios considered for future land use include: residential, industrial, agricultural and recreation. Of the possible future land uses, residential land use generally yields the highest exposures because of the long exposure frequency and duration for this population. Therefore, the residential scenario is assumed to be the most conservative future scenario and the most appropriate land use to consider when estimating risks or hazards.

Pathways that were excluded from consideration at a specific site were done so using the following rationale:

- Sampling was not performed because the medium and/or contaminant was not considered to be of concern
- The contaminant source applicable to the specific pathway has been shown to not exist based on sampling results
- The transport mechanism for the pathway does not exist at the site
- The receptor does not exist at the site
- The exposure route cannot exist at the site for other reasons

In addition, on a site-by-site basis, certain pathways may not have been quantified because: (1) the exposure resulting from the pathway is much less than that from another analogous pathway; (2) the potential magnitude of the exposure is low; or (3) the probability of the exposure occurring is very low.

Pathways included for quantification for the Miscellaneous Sites are summarized in Table 1-4 for current land use and Table 1-5 for future land use.

For each quantified pathway, an average daily intake is calculated using a variety of assumptions including: receptor body weight; frequency of exposure; exposure duration;

Table 1-4: Exposure Pathways Quantified at the Miscellaneous Sites - Current Land Use Scenario

Site No.	Exposure Pathway 1	2	3	4	5	6	7	8	9	10	11	12
3, Hazardous waste storage facility	I	I	I	I	I	I	I	I	I	I	I	I
6, Sewage treatment plant	I	I	I	I	I	I	I	I	I	I	I	I
9, Remote munitons disassembly GB bomb area	I	I		I	I	I	I	I	I	I	I	I
10, Former agent H storage area	I	I		I	I	I	I	I	I	I	I	I
22, Defense reutilization marketing office area	I			I	I	I	I	I	I	I	I	I
25I, Metal ore piles - location I	I	I		I	I	I	I	I	I	I	I	I
25II, Metal ore piles - location II	I	I		I	I	I	I	I	I	I	I	I
26, Metal ingot stockpiles	I	I		I	I	I	I	I	I	I	I	I
27, Pesticide storage building	I	I		I	I	I	I	I	I	I	I	I
29 #420, Septic tanks	I	I	I	I	I	I	I	I	I	I	I	I
29 #417, Septic tanks	I	I	I	I	I	I	I	I	I	I	I	I
29 #486, Septic tanks	I	I	I	I	I	I	I	I	I	I	I	I
29 #655-1, Septic tanks	I	I	I	I	I	I	I	I	I	I	I	I
29 #655-2, Septic tanks	I	I	I	I	I	I	I	I	I	I	I	I
29 #622, Septic tanks	I	I	I	I	I	I	I	I	I	I	I	I
30, Stormwater discharge area	I	I	I	I	I	I	I	I	I	I	I	I
33, Gravel pit disposal area	I	I	I	I	I	I	I	I	I	I	I	I
34, Paint spray and shot blast areas	I	I	I	I	I	I	I	I	I	I	I	I
35, Malathion storage leak area	I	I	I	I	I	I	I	I	I	I	I	I
36, Building 493 paint sludge discharge area	I	I		I	I	I	I	I	I	I	I	I
37, Bldg. 131 paint sludge discharge area	I			I	I	I	I	I	I	I	I	I
39, QA function range	I	I		I	I	I	I	I	I	I	I	I
44I, Road oil application disposal sites	I	I	I	I	I	I	I	I	I	I	I	I
44II, Road oil application/disposal sites	I	I	I	I	I	I	I	I	I	I	I	I
45 (612), Bldg. 612 & Bldg. 617 boiler disch. areas	I	I		I	I	I	I	I	I	I	I	I
45 (617), Bldg. 612 & Bldg. 617 boiler disch. areas	I	I		I	I	I	I	I	I	I	I	I
46, Railcar unloading area	I			I	I	I	I	I	I	I	I	I
47, Boiler/laundry effluent discharge area	I	I		I	I	I	I	I	I	I	I	I
48, Pipe discharge area	I	I	I	I	I	I	I	I	I	I	I	I
49, Drill and transfer (DAT) site	I	I	I	I	I	I	I	I	I	I	I	I
50, Railroad landfill areas	I	I	I	I	I	I	I	I	I	I	I	I
52, Coyote Coulee discharge gullies	I	I		I	I	I	I	I	I	I	I	I

Source: Reference 4 and Arthur D. Little, Inc.

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Table 1-4: Exposure Pathways Quantified at the Miscellaneous Sites - Current Land Use Scenario (continued)

Site No.	Exposure Pathway 1	2	3	4	5	6	7	8	9	10	11	12
53, Bldg. 433 collection sump/cistern and disposal area	I	I		I	I	I	I	I	I	I	I	I
67, Bldg. 493 brass cleaning operations area	I	I		I	I	I	I	I	I	I	I	I
80, Disposal pit and graded area	I	I	I	I	I	I	I	I	I	I	I	I
81I, Former raw materials storage	I	I		I	I	I	I	I	I	I	I	I
81II, Former raw materials storage	I	I	I	I	I	I	I	I	I	I	I	I
82, Former gravel pit/disposal location	I	I	I	I	I	I	I	I	I	I	I	I

I - The pathway is incomplete for the reasons indicated in text

Indicates that the exposure pathway was quantified for the site

Note: Ground water data were grouped as follows for certain sites since contamination in these wells may originate from any site within the group: Sites 4, 47, 67 (flood gravel and basalt aquifers)

Source: Reference 4 and Arthur D. Little, Inc.

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Table 1-5: Exposure Pathways Quantified at the Miscellaneous Sites - Future Residential Land Use Scenario

	Exposure Pathway											
Site No.	1	2	3	4	5	6	7	8	9	10	11	12
3, Hazardous waste storage facility	I	I	I	I	I	I	I	I	I	I	I	I
6, Sewage treatment plant	I	I	I	I	I	I	I	I	I	I	I	I
9, Remote munitons disassembly GB bomb area				I	I	I	I	I	I	I	A	
10, Former agent H storage area	I			I	I	I	I	I	I	I	A	
22, Defense reutilization marketing office area	D			I	I	I	I	I	I	I	A	
25I, Metal ore piles - location I	I			I	I	I	I	I	I	I	A	
25II, Metal ore piles - location II	I			I	I	I	I	I	I	I	A	
26, Metal ingot stockpiles	I			I	I	I	I	I	I	I	A	
27, Pesticide storage building	D			I	I	I	I	I	I	I	A	
29 #420, Septic tanks	I	I	I	I	I	I	I	I	I	I	I	I
29 #417, Septic tanks	I	I	I	I	I	I	I	I	I	I	I	I
29 #486, Septic tanks	I	I	I	I	I	I	I	I	I	I	I	I
29 #655-1, Septic tanks	I	I	I	I	I	I	I	I	I	I	I	I
29 #655-2, Septic tanks	I	I	I	I	I	I	I	I	I	I	I	I
29 #622, Septic tanks	I	I	I	I	I	I	I	I	I	I	A	
30, Stormwater discharge area	D			I	I	I	I	I	I	I	A	
33, Gravel pit disposal area	I	I	I	I	I	I	I	I	I	I	I	I
34, Paint spray and shot blast areas	D			I	I	I	I	I	I	I	A	
35, Malathion storage leak area	D			I	I	I	I	I	I	I	A	
36, Building 493 paint sludge discharge area	I			I	I	I	I	I	I	I	A	
37, Bldg. 131 paint sludge discharge area	D			M,A	I	I	I	I	I	I	A	
39, QA function range	I			I	I	I	I	I	I	I	A	
44I, Road oil application disposal sites	I	I	I	I	I	I	I	I	I	I	I	I
44II, Road oil application/disposal sites	I	I	I	I	I	I	I	I	I	I	I	I
45 (612), Bldg. 612 & Bldg. 617 boiler disch. areas	I			I	I	I	I	I	I	I	A	
45 (617), Bldg. 612 & Bldg. 617 boiler disch. areas	I			I	I	I	I	I	I	I	A	
46, Railcar unloading area	D			I	I	I	I	I	I	I	A	
47, Boiler/laundry effluent discharge area				I				A	A	I	A	
48, Pipe discharge area	D			I	I	I	I	I	I	I	A	
49, Drill and transfer (DAT) site	I	I	I	I	I	I	I	I	I	I	I	I
50, Railroad landfill areas	I	I	I	I		I		A	I	I	A	
52, Coyote Coulee discharge gullies				I	I	I	I	I	I	I	A	
53, Bldg. 433 collection sump/cistern and disposal area	D			I	I	I	I	I	I	I	A	
67, Bldg. 493 brass cleaning operations area	I			I				A	A	I	A	
80, Disposal pit and graded area	I	I	I	I	I	I	I	I	I	I	I	I

Table 1-5: Exposure Pathways Quantified at the Miscellaneous Sites - Future Residential Land Use Scenario (continued)

Site No.	Exposure Pathway 1	2	3	4	5	6	7	8	9	10	11	12
81I, Former raw materials storage	I			I	I	I	I	I	I	I	A	
81II, Former raw materials storage	I	I	I	I	I	I	I	I	I	I	I	I
82, Former gravel pit/disposal location	I	I	I	I	I	I	I	I	I	I	I	I

I - The pathway is incomplete for the reasons indicated in text.

M- The pathway is excluded from quantification because the potential magnitude of exposure is small and associated risks are low.

D- The pathway is excluded because data on dermal absorption of all contaminants of concern from soil are not available.

[shaded box] Indicates that the exposure pathway will be quantified for the site

A- The pathway is excluded from quantification because the expected exposure and risks are much less than from another pathway involving the same medium and exposure point.

Note: Ground water data were grouped as follows for certain sites since contamination in these wells may originate from any site within the group: Sites 4, 47, 67 (flood gravel and basalt aquifers)

Source: Reference 4 and Arthur D. Little, Inc.

respiration rates; absorption factors; skin surface areas; and ingestion rates. For detail regarding specific parameters that are included in the individual pathways, refer to the RA.

1.2.5.4 Human Health Risk Evaluation. The purpose of the human health risk evaluation is to relate exposure estimates to toxicity to estimate the potential health hazards and/or risks posed by the contaminated media.

The risk evaluation is conducted by combining the toxicological data with the average daily intakes. For the Miscellaneous Sites pathways, potential incremental cancer risks (risks) are calculated by multiplying the daily intake averaged over the receptor's lifetime by the SF. According to the NCP, acceptable exposure levels resulting from these calculations are generally those that represent an excess upperbound lifetime cancer risk to an individual of between 1×10^{-4} and 1×10^{-6}.

Hazard quotients (HQs) are calculated for noncarcinogenic risks by dividing the average daily intake by the RfD. Risks and HQs are calculated for each pathway and then summed to yield the total site risk and HQ. Human health hazards related to exposure are generally considered of concern when the HQ exceeds 1.

It is acknowledged that the total risks and HQ for each pathway are probably overestimated, because combining risk and hazard quotients assumes the additivity of toxic effects within the human body when, in fact, chemicals with different mechanisms of toxic action may act independently[4].

In addition to the calculations described above, an uptake/biokinetic model was used in the RA to evaluate potential exposure to lead at the Miscellaneous Sites. The evaluation was conducted for the various sites at UMDA where lead concentrations in soil exceed 200 ppm. The results of application of this model indicate that several sites have lead concentrations that may yield unacceptable exposure levels. The exact number of sites will depend on the percentage of the population to be protected and the blood lead cutoff level selected. The implications of this calculation will be presented in Section 1.2.5.5, Risk-Based Remedial Action Criteria.

1.2.5.4.1 Current Land Use Scenarios. Under the current land use scenarios, contaminated dust from multiple sites at the Miscellaneous Sites may be inhaled by either on-site or off-site receptors. Multiple pathway total risks and HQs for these scenarios are summarized in Table 1-6. The highest risk calculated for any of the receptors was 7×10^{-7} and the highest HQ was 0.20, both of which are considered acceptable risk levels.

1.2.5.4.2 Future Land Use Scenarios. Risks and HQs for the following sites were not quantified during the risk assessment: 3, 6, 29, 33, 44, 49, 80, 81II, and 82. These sites were excluded because either all of the pathways were excluded based on the rationale provided in the Exposure Assessment; and/or ground water data from that site were grouped with other sites because the contaminant source was unknown.

Table 1-6: Summary of Total Risks and Hazard Quotients for Current Land Use Scenarios

Recepter	Pathway(s) (a)	Risk	HQ
1. Worker-Near Explosives Washout Area at Building 419	Dust inhalation (3)	$8x10^{-8}$	$9x10^{-3}$
2. Open detonation pit and open burning tray workers	Dust inhalation (3)	$8x10^{-7}$	$2x10^{-1}$
3. Target range users	Incidental soil ingestion (2) and dust inhalation (3)	$1x10^{-9}$	$8x10^{-4}$
4. Worker in southwest warehouse area	Incidental soil ingestion (2) dust inhalation (3) and dermal contact with soil (1)	$4x10^{-8}$	$7x10^{-3}$
5. Worker near DRMO Building	Incidental soil ingestion (2), dust inhalation (3) and dermal contact with soil (1)	$2x10^{-8}$	$1x10^{-2}$
6. Pesticide worker	Inhalation of dust (3)	$5x10^{-10}$	$7x10^{-5}$
7. Workers at Buildings 612 and 617	Dermal contact with soil (1), soil ingestion (2), dust inhalation (3)	$2x10^{-7}$	$2x10^{-2}$
8. Eastern boundary residents	Dust inhalation (3)	$8x10^{-8}$	$8x10^{-3}$
9. Hermiston residents	Dust inhalation (3)	$6x10^{-8}$	$5x10^{-3}$
10. Western boundary residents	Dust inhalation (3)	$7x10^{-8}$	$3x10^{-2}$
11. Irrigon residents	Dust inhalation (3)	$1x10^{-8}$	$3x10^{-3}$

Risk - Incremental cancer risk
HQ - Hazard quotient
(a) - Pathway descriptions and numbers
Source: Reference 4 and Arthur D. Little, Inc.

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For the future scenario, primarily only residential land use was evaluated. Several sites were also evaluated for additional future scenarios. The risk characterization for future land use is summarized in Table 1-7. This table includes the quantified pathways, total risk, and total HQs, and indicates that:

- For future residential use, risks and hazards are below a cancer risk of 1×10^{-6} and an HQ of 1 at Sites 3, 6, 9, 10, 26, 27, 29, 33, 34, 35, 39, 44I, 44II, 45, 46, 49, 52, 53, 80, 81I, 81II, and 82.

- For future residential use, risks and hazards are below a cancer risk of 1×10^{-5} and HQ of 1 at the additional Sites 30, 48, and 50.

1.2.5.4.3 Ground Water at the Miscellaneous Sites. The above discussion reflects contamination and resulting risks and hazards relating to both ground water and soil at the Miscellaneous Sites. Although both media contribute to the overall risks and hazards, a few observations with respect to ground water at the Miscellaneous Sites need to be discussed.

One of the conclusions of the RI was that the spread of contamination due to contaminants in the soil was through windblown dust. There was no evidence in the few ground water analyses that migration of contaminants in soil was responsible for ground water contamination beneath the Miscellaneous Sites. This conclusion is supported by the general absence of any specific correlation between contaminants of concern in soil and ground water as well as the lack of evidence that contaminants of concern in ground water have any relation to activities performed at the Miscellaneous Sites.

For the most part, ground water characterizations at the Miscellaneous Sites indicated the presence of various levels of inorganic elements or compounds that were identified in background ground water characterizations. In addition, these inorganics were consistently identified across the entire installation and were not restricted to the Miscellaneous Sites.

Exceptions to the background contamination occurred in the ground water beneath Sites 47 and 67. These sites are adjacent to Site 4 (Washout Lagoons) where the ground water was contaminated by the washout water from munition processing. The ground water plume that underlies Sites 47 and 67 is being addressed in a separate FS for Operational Unit 3. For this reason, this plume of ground water will not be considered further in this FS.

Based on the discussion above, the remediation of ground water will not be addressed in this FS. Although ground water remediation will not be addressed, its contribution to the total risks and hazards as imposed by exposure pathways 5, 6, and 7 will be continued throughout the FS. To illustrate the impact of these pathways on the total risks and hazards associated with future residential use, Table 1-8 has been prepared to reflect a

Table 1-7. Summary of Total Risks and Hazard Quotients For Future Residential Use

Site	Residential		
	Pathways	Risk	HQ
3	NC	NC	NC
6	NC	NC	NC
9	1,2,3	8E-07	0.3
10	1,2,3	NC	0.06
22	2,3	3E-07	1
25I	2,3	NC	2
25II	2,3	4E-09	1
26	2,3	0E+00	0.005
27	2,3	1E-08	0.004
29	NC	NC	NC
30	2,3	1E-06	0.01
33	NC	NC	NC
34	2,3	2E-07	0.06
35	2,3	3E-07	0.002
36	2,3	8E-07	9
37	2,3	6E-06	0.2
39	2,3	NC	0.06
44I	NC	NC	NC
44II	NC	NC	NC
45	2,3	2E-08	0.1
46	2,3	3E-07	0.05
47	1,2,3,5,6,7	3E-03	30
48	2,3	5E-06	0.1
49	NC	NC	NC
50	5,7	1E-04	0.8
52	1,2,3	1E-07	0.02
53	2,3	7E-09	0.09
67	2,3,5,6,7	2E-03	60
80	NC	NC	NC
81I	NC	NC	NC
81II	2,3	NC	0.00003
82	NC	NC	NC

HQ - Hazard Quotient

NC - Not Calculated

Table 1-8. Detail of Future Residential Use Risks and Hazard Quotients

Site	Total (a)			Ground Water-Related			Non-Ground Water-Related		
	Pathways	Risk	HQ	Pathways	Risk	HQ	Pathways	Risk	HQ
3	None			None			None		
6	None			None			None		
9	1,2,3	8E-07	0.3	None			1,2,3	8E-07	0.3
10	1,2,3	NC	0.06	None			1,2,3	NC	0.06
22	2,3	3E-07	1	None			2,3	3E-07	1
25-I	2,3	NC	2	None			2,3	NC	2
25-II	2,3	4E-09	1	None			2,3	4E-09	1
26	2,3	0E+00	0.005	None			2,3	0E+00	0.005
27	2,3	1E-08	0.004	None			2,3	1E-08	0.004
29	None			None			None		
30	2,3	1E-06	0.01	None			2,3	1E-06	0.01
33	None			None			None		
34	2,3	2E-07	0.06	None			2,3	2E-07	0.06
35	2,3	3E-07	0.002	None			2,3	3E-07	0.002
36	2,3	8E-07	9	None			2,3	8E-07	9
37	2,3	6E-06	1	None			2,3	6E-06	1
39	2,3	NC	0.06	None			2,3	NC	0.06
44-I	None			None			None		
44-II	None			None			None		
45	2,3,	2E-08	0.1	None			2,3,	2E-08	0.1
46	2,3	3E-07	0.05	None			2,3	3E-07	0.05
47	1,2,3,5,6,7	3E-03	30	5,6,7	3E-03	30	1,2,3	1E-07	2
48	2,3	5E-06	0.1	None			2,3	5E-06	0.1
49	None			None			None		
50	5,7	1E-04	0.8	5,7	1E-04	0.8	None		
52	1,2,3	1E-07	0.02	None			1,2,3	1E-07	0.02
53	2,3	7E-09	0.09	None			2,3	7E-09	0.09
67	2,3,5,6,7	2E-03	60	5,6,7	2E-03	60	2,3	0E+00	0
80	None			None			None		
81-I	None			None			None		
81-II	2,3	NC	0.00003	None			2,3	NC	0.00003
82	None			None			None		

Source: Reference 4

(a) Numbers may not add due to rounding
HQ - Hazard Quotient
NC - Not Calculated

Source: Reference 4

breakdown of risks and hazards associated with specific ground water-related and non-ground water-related exposure pathways.

1.2.5.5 Risk-Based Remedial Action Criteria. For each of the land use scenarios, risk-based preliminary remediation goals (PRGs) were developed as part of the RA. Risk-based PRGs indicate acceptable residual contaminant concentrations based on the following target human health risk values: incremental cancer risks equal to $1x10^{-6}$ and hazard quotients equal to 1. The risk-based PRGs are back-calculated from the target risk levels for each contaminant in each media. Risk-based PRGs are not calculated for the current land use scenario because all current cancer risks and HQs fall below the target values of $1x10^{-6}$ (cancer risk) and 1.0 (HQ).

The single exception to this method of calculation of risk-based PRGs is lead. An action level of 500 μg/g has been established for lead at the Miscellaneous Sites[17]. Based on the uptake/biokinetic model used in the RA to evaluate potential exposure to lead, a residual concentration of 500 μg/g would result in 92 percent of children having blood lead levels of less than or equal to 10 μg/dL and greater than 99.5 percent of the children would have blood lead levels of less than or equal to 15 μg/dL.

A summary of risk-based PRGs calculated for contaminants in soil at the Miscellaneous Sites is presented in Table 1-9. Note that only risk-based PRGs for contaminants in soil are provided, since it has been determined that ground water remediation will not be addressed in this FS (see Section 1.2.5.4.3).

One point of note with respect to the risk-based PRGs presented in Table 1-9 is that, in several instances (barium, cadmium, and chromium, for example), risk-based PRGs for the light industrial scenarios are considerably lower than those for the residential use scenario. This is in contrast to the general assumption that the residential use scenario provides the most conservative approach. Based on these "anomalies," this assumption may not always be the case. Examination of the calculations involved in determining the risks and hazards associated with ingestion and inhalation of contaminated dust confirms this. In these calculations, it was assumed that future light industrial workers would be located and performing routine activities closer to the source of dust emissions and therefore would be exposed to higher concentrations of contamination. For the protection of such workers and personnel, the soils where the dust originates would have to be less contaminated (with respect to specific contaminants) than would be required for residents. Modeled air concentrations supporting these observations are provided in Appendix E, Table E-6 of the RA.[4]

1.2.6 Ecological Risk Assessment

The following discussion provides a brief summary of the Ecological Assessment (EA) performed for UMDA as presented in the Draft Final Ecological Assessment Report[18]. For a detailed account of the EA, refer to the referenced EA report.

Table 1-9. Risk-Based Preliminary Remedial Goals for Contaminants of Concern in Soil

Contaminant of Concern	Future Use Scenario Residential Risk-based (a) ug/g	Light Industrial Risk-based (b) ug/g	Light Industrial Risk-based (c) ug/g
Antimony	110	818	818
Barium	13700	861	861
Cadmium	127	2.75	27.5
Calcium	-	-	-
Chromium	19	0.413	4.13
Cobalt	2.74	20.2	20.2
Copper	10100	34000	75600
Lead	(d)	(d)	(d)
Magnesium	-	-	-
Mercury	81.9	292	292
Nickel	470	10.2	102
Selenium	1370	10200	10200
Silver	1370	10200	10200
Thallium	21.9	164	164
Vanadium	1920	14300	14300
Zinc	54800	14300	409000
Cyanide	5480	40900	40900
Nitrate/nitrite	438000	NA	NA
HMX	1050	2270	2270
RDX	5.81	52	520
Benzo(a)anthracene	0.11	0.732	7.32
Benzo(b)fluoroanthrene	0.11	0.732	7.32
Benzo(k)fluoroanthrene	0.11	0.732	7.32
Chrysene	0.11	0.732	7.32
Di-n-butyl phthalate	27400	204000	204000
Fluoranthene	10900	81800	81800
Phenanthrene	-	-	-
Pyrene	8210	61300	61300
Chlordane	0.491	3.31	33.1
DDD	2.66	23.8	238
DDE	1.88	16.8	168
DDT	1.88	12.7	127
PCB-1260	0.083	0.108	1.08

A dashed entry (-) indicates that relevant health effects criteria are unavailable
NA - Not Applicable because calculated PRG is greater than 1E+06 ppm
(a) Based on a Residential cancer risk of 1E-06 or an HQ of 1
(b) Based on a Light Industrial cancer risk of 1E-06 or an HQ of 1
(c) Based on a Light Industrial cancer risk of 1E-05 or an HQ of 1
(d) Action level for lead established at 500 ug/g

Source: Reference 4

1.0 Introduction

The EA involved the conduct of a multi-step process to evaluate the affects and potential affects to site biota from contaminants in soil at UMDA. These steps included[18]:

- Evaluation of site activities resulting in the chemical releases
- Characterization of the installation's physical features, habitats, and potentially exposed biota, and identification of indicator species
- Observation of habitat disruptions potentially related to toxic effects
- Identification of contaminants of concern and potential exposure pathways
- Summarization of environmental fate for the contaminants of concern
- Assessment of the exposure and toxicity potential of contaminants of concern to selected indicator species
- Characterization of risk

The toxicity and environmental fate of contaminants of concern were evaluated on an installation-wide basis for contaminants found at or near the surface. Thirty contaminants of concern were identified at locations at which wildlife might be exposed. These contaminants of concern were identified as those contaminants that were above background soil levels or not naturally occurring in the environment as determined in the RI. The 30 contaminants of concern identified in the EA include metals, nitroaromatic compounds (explosives and their derivatives), and pesticides. Of these contaminants of concern, the most significant (across the entire installation) in terms of volume, distribution and relative toxicity, are lead; zinc; aluminum; 2,4,6-TNT; HMX; RDX; and tetryl[18].

The potency of the contaminants of concern to environmental receptors (indicator species) was calculated based on exposure point concentrations and certain assumptions concerning the duration of exposure. A full discussion of these calculations and assumptions is provided in the EA report.

The chronic toxicity imposed by the contaminants of concern was developed by comparing calculated daily contaminant uptake rates to NOAELs for four indicator species The indicator species selected for use in these calculations were the field mouse, the pronghorn antelope, the American badger, and the Swainson's hawk.

Daily contaminant uptake rates were calculated for the oral ingestion pathway only. These calculations were based on a total ingestion dose as a function of contaminant concentration in soil and the species ingestion rate of soil. Specific ingestion pathways considered include:

- Feeding on vegetation
- Feeding on prey in intimate contact with the soil
- Preening
- Burrowing
- Direct ingestion by soil licking or eating (to obtain available salts contained in the soil)

Exposure potentials for the indicator species at the Miscellaneous Sites were determined and are summarized as follows:

- Field Mouse - The field mouse has a home range that is significantly smaller than the areal distribution of contaminated soils at the Miscellaneous Sites. For this reason, the field mouse may be directly and continuously exposed to the contaminants where its range is coincident with contamination.

- Pronghorn Antelope - Present exposure potential for the pronghorn is low at the Miscellaneous Sites since lead, zinc, and DDD are not chronic toxicity hazards and other contaminants are highly localized.

- Badger - Badgers have a large home range, estimated at several times larger than the areal extent of contamination. They may be occasionally exposed to acutely toxic doses of contaminants if they seek prey in the most contaminated sites of the Miscellaneous Sites. Because of their large home ranges, it is suggested that chronic exposures would be unlikely.

- Swainson's hawk - The contaminated areas at UMDA represent about 10 percent of the overall hunting range of this hawk. The hawk is a migratory species and therefore only a transient resident at UMDA. In addition, preferred habitat is found in abundance off site. For these reasons, acute exposure potential is expected to be low and chronic exposure potential may be minuscule.

Hazard quotients (HQs), represented by the ratio of the contaminant intake to the NOAEL, were calculated. An HQ of greater than one is indicative of the possibility of adverse health effects resulting from exposure to a specific contaminant.

A summary of the risk characterization performed for the principal contaminants of concern at the Miscellaneous Sites (as identified in the EA) is presented in Table 1-10. Only the lead concentrations at Site 30 are of concern to the field mouse and hawk under the worst-case chronic exposure, indicating that lead is a slight to moderate potential health hazard for these species. However, the lead concentrations at Site 30 are below background levels for the UMDA and thus will not impact the development of the PRGs.

Table 1-10. Risk Characterization Summary for the Principal Contaminants of Concern at the Miscellaneous Sites

Indicator Species	Principal Contaminant of Concern	Worst-Case Chronic HQ (Site)	Comments
Field Mouse	Lead	14.4 (30)	Silver, zinc, and DDT were not chronic toxicity hazards, toxicological data were not available for other contaminants
Pronghorn			Lead, zinc, and DDD were not chronic toxicity hazards, toxicological data were not available for other contaminants
Badger			Lead chronic HQ was slightly above one; silver, zinc, and DDT were not chronic hazards; toxicological data were not available for other contaminants
Hawk	Lead	6.49 (30)	DDD, DDE, and DDT were not chronic toxicity hazards; toxicological data were not available for other contaminants

Source: Reference 18

2.0 Identification and Screening of Technologies

2.1 Introduction

The primary objective of this phase of the FS is to develop an appropriate range of technology types and process options that will protect human health and the environment by eliminating, reducing, and/or controlling risks posed by the contaminated media. These technology types and process options are then assembled into remedial alternatives (Section 3.0, Development of Alternatives) that are then assessed in the detailed analysis (Section 4.0, Detailed Analysis of Alternatives).

Prior to the development of technology types and process options, remedial action objectives that specify the contaminants and media of concern, exposure pathways, and preliminary remediation goals were developed. The preliminary remediation goals were selected based on the ARARs and the Human Health Baseline Risk Assessment [4].

Once the remedial action objectives were developed, the volume of contaminated soil to be remediated was estimated based on the results of the RI [2]. Using the estimated amount of soil to be remediated and the developed remedial action objectives, potential technologies and process options were identified and screened to eliminate those technologies that were not applicable to remediate the site. Applicable process options were then identified and evaluated for effectiveness, implementability, and cost. This procedure resulted in the selection of technology types and process options to be incorporated into the remedial alternatives.

The detailed description of the technology identification and screening phase is presented in the remaining sections following the outline provided by EPA in the *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA*[3].

2.2 Remedial Action Objectives

The development of remedial action objectives is a critical step in the FS process because they are the basis by which technologies and process options will be evaluated. The development of remedial action objectives involves addressing the following: 1) contaminants of concern; 2) Applicable or Relevant and Appropriate Requirements (ARARs); 3) allowable exposures based on the risk assessment; and 4) development of remedial action goals.

2.2.1 Contaminants of Concern

Contaminants of concern at the Miscellaneous Sites are those contaminants that were identified in the remedial investigation(s) and met certain criteria. The selection of contaminants of concern is described in detail in Section 1.2.5.1, Selection of Contaminants of Concern. Summaries of contaminants of concern identified for each site of the Miscellaneous Sites (in both ground water and soil) are provided in Tables 1-1 and 1-2.

It should be noted that the presence of a contaminant of concern at a site is not necessarily an indication that the site will require remediation. Site remediation requirements will depend on the remedial goals that are established. These remedial goals will be discussed in Section 2.2.4, Development of Remedial Action Goals.

The remainder of this FS primarily addresses issues relating to the remediation of soil at the Miscellaneous Sites. The remediation of ground water will not be addressed for the reasons described in **Section 1.2.5.4.3, Ground Water at the Miscellaneous Sites**. Although ground water remediation will not be addressed, its contribution to the total risks and hazards imposed by contaminated media at the Miscellaneous Sites will be carried throughout the FS.

In general, the types of contaminants of concern in Miscellaneous Sites soils include metals and other organics. Contamination of soil by metals at a wide range of concentrations occurs virtually at every site at the Miscellaneous Sites. Organic contamination is less widespread and typically concentrations are very low.

2.2.2 Applicable or Relevant and Appropriate Requirements (ARARs)

The selection of ARARs is dependent on the hazardous substances present at the site, the site characteristics and location, and the actions selected for a remedy. Consequently, ARARs are characterized as follows:

- Chemical-specific
- Location-specific
- Action-specific

Chemical-specific ARARs are health- or risk-based concentration limits set for specific hazardous substances, pollutants, or contaminants. Location-specific ARARs address physical environmental conditions such as the presence of wetlands on the site or the location of 100-year floodplains. Action-specific ARARs control or restrict particular types of remedial actions as alternatives for cleanup.

2.2.2.1 Chemical-Specific ARARs. In developing chemical-specific ARARs, both state and federal regulations were considered. These chemical-specific ARARs are summarized in Table 2-1.

land disposal restrictions and must meet the treatment standard for the contaminating waste prior to land disposal. However, EPA realizes that certain problems are associated with regulating hazardous wastes in soil. Because of such problems, EPA is preparing a separate rule making that will establish treatability groups and treatment standards for

Table 2-1: Chemical-Specific Applicable or Relevant and Appropriate Requirements (ARARs)

Medium/ Authority	Requirements	Status	Requirement Synopsis	Action to be Taken to Attain ARAR
Federal Regulatory Requirements	RCRA Land Disposal Restrictions (LDR) (40 CFR 268)	Applicable	Remedial activities that involved the movement of excavated materials to a new location and placement in or on land or that generate residual hazardous wastes will trigger land disposal restrictions. Soil and debris contaminated with prohibited wastes must meet the treatment standard for the contaminated waste prior to land disposal.	Any wastes subject to LDR must be treated using best demonstrated available treatment technologies for each hazardous constituent in each listed or characteristic waste.
State Regulatory Requirements	Oregon Hazardous Substance Remedial Action Rules	Applicable	Requires that if hazardous substances are released, the environment shall be restored to background conditions if feasible.	Background conditions are to be met unless background conditions are not feasible. If background conditions are not feasible, the environment is to be restored to the lowest levels that are protective (in terms of public health, safety, and welfare and the environment) and feasible.

contaminated soil. Until contaminated soil can be better organized into treatability groups, however, promulgated treatment standards for the individual or types of wastes would be applicable ARARs.

Since some of the remedial options could involve treatment of the soil and subsequent land disposal, the RCRA land disposal requirements would be an applicable ARAR and subject the treatment to meeting chemical-specific treatment standards. The applicability of RCRA is discussed in Section 2.2.2.3, Action-Specific ARARs.

State ARARs - Soil

Oregon Soil Cleanup Standards - The Oregon Hazardous Substance Remedial Action Rules (OAR 340-122)[19] provide guidance for determining contaminant cleanup levels on a site-specific basis. These rules have been identified as applicable for the remediation of contaminated soil.

These rules state that in the event of a release of a hazardous substance, the environment shall be restored to:

- Specific Numerical Soil Cleanup Levels as specified in OAR 340-122-045 if applicable; or

- Background levels unless is it determined that remedial actions designed to attain Background Level do not meet the certain "feasibility " requirements in which event the environment shall be restored to the lowest concentration level in accordance with OAR 340-122-090, which provides guidance for remedial action selection.

Of the general types of contaminants of concern at the Miscellaneous Sites (metals and organics), the organics can be considered to be not naturally occurring. Therefore, the background concentration would be essentially zero or, for practical purposes, below detection limits. If a remedial alternative proposed in this FS cannot achieve background, a risk assessment approach must be used to demonstrate that the action achieves the lowest cleanup level that protects human health and the environment.

2.2.2.2 Location-Specific ARARs. Location-specific ARARs set restrictions on remedial action activities depending upon the characteristics of a site and/or its immediate environs. These ARARs are contained in a number of federal statutes and regulations. In addition, the state of Oregon has requirements that may apply in a given situation. Regulations that may be considered as location-specific ARARs for UMDA are summarized in Table 2-2.

In addition to the ARARs discussed in each of the following sections, consideration should also be given to the local planning requisites in both Morrow and Umatilla Counties. Oregon law mandates that each county and community develop, and have

Table 2-2: Location-Specific Applicable or Relevant and Appropriate Requirements (ARARs)

Medium/ Authority	Requirements	Status	Requirement Synopsis	Action to be Taken to Attain ARAR
Federal Regulatory Requirements	Clean Water Act (CWA) Section 404(b) (40 CFR 230; 33 CFR 320-330)	Applicable if Wetlands are Affected	No discharge of dredged or fill material shall be permitted if there is a practical alternative that has less adverse impact on the aquatic ecosystem, so long as the alternative does not have other significant adverse environmental consequences. Appropriate and practical steps must be taken that will minimize the potential adverse impacts on the aquatic ecosystem.	There will be no discharge of dredged or fill materials into wetlands.
	Endangered Species Act (16 USC 1531 et seq.; 40 CFR 502)	Applicable	This Act requires the conservation of endangered and threatened species within critical habitats.	The U.S. Fish and Wildlife Service will be consulted to determine whether remedial actions are likely to jeopardize any endangered or threatened species. No remedial actions will proceed that will negatively affect endangered or threatened species.

approved by the state, a comprehensive land use plan that must take into consideration many of the same concerns addressed in this discussion. Consultation with the appropriate county officials and cognizance of their land use plans and goals would increase the efficacy of any actions proposed or taken at UMDA.

Federal ARARs

Caves, Salt-dome Formations, Salt-bed Formations, and Underground Mines. The bedrock under UMDA and the surrounding area consists of basalt laid down by lava flows during the Miocene Period. This is capped by a mixture of Pleistocene alluvial deposits, including clays, sands, silts, gravels, and some boulders. There are sedimentary interbeds between the lava flows and this type of rock also has tunnels and occasional "lava holes". However, there are no indications of caves, salt-dome formations, salt bed formations or underground mines on the site, nor would such features normally be expected with a structural bedrock of basaltic lava flows. Thus no ARARs are identified for this category.

Faults. UMDA is surrounded by four structural features: the Service Anticline on the east, an anticline on the west, the Dalles-Umatilla Syncline to the north, and a monocline to the south. The Service anticline runs north to south and is faulted on both its east and west dips. There are active Holocene faults approximately 50 to 80 miles north of the site, near the Hanford Nuclear Reservation in Washington State. There is also a suspected active Holocene fault approximately 70 miles southeast of the depot near LeGrand, Oregon. However, none of the faulting associated with the Service Anticline is documented or believed to have been displaced during the Holocene period, nor is it considered active.

Because of the surrounding areas' history of low seismicity, UMDA is exempted from compliance with the RCRA seismic requirements of 40 CFR 264.18. 40 CFR 264.18(a) stipulates that all facilities located within political jurisdictions other than those listed in Appendix VI are assumed to be in compliance for location of new treatment, storage, or disposal (TSD) facilities. Oregon is not listed in this Appendix, thus the location-specific standards in 40 CFR 264.18(a) for siting a hazardous waste treatment, storage, or disposal facility are not an ARAR.

Wilderness Areas, Wildlife Refugees, and Scenic Rivers. There are no designated wilderness areas within UMDA, or in its immediate vicinity. Neither the Columbia River nor the Umatilla River, both of which lie within 3 miles of the depot, have been designated as scenic rivers.

*Wetlands and Floodplains.*The Columbia River is now largely dam-controlled, thus eliminating most concerns with flooding hazards. Available information indicates that UMDA is not located within 100- or 500-year floodplains and therefore no ARARs were identified in this category.

There are a number of wetlands in the immediate area of UMDA, to the east, west, and south. Those associated with the Umatilla River on the east come within at least 1 mile of the site. Additionally, the wetlands located near the northwest corner of the depot extend to the boundary of the UMDA. Wetlands located to the west of UMDA are associated with Irrigon State Wildlife Refuge and other wetlands to the south are 2.5 to 3.5 miles from the depot.

At the federal level, the ARARs pertinent to wetlands include Section 404 of the Clean Water Act (CWA) and Executive Order 11990 on Wetlands Protection. Since remediation activities at UMDA will not include the discharge of dredged or fill material, as defined in 33 CFR 323.2(d), Section 404 of the CWA is not applicable. However, a guiding principle of 40 CFR Part 230 is that degradation or destruction of wetlands should be avoided to the extent possible. Executive Order 11990 requires federal agencies to minimize the destruction, loss, or degradation of wetlands and preserve and enhance natural and beneficial values of wetlands.

Since none of the identified wetlands are actually on the site, there would be no applicable ARARs specifically for on-site actions unless remedial actions have the potential to affect wetlands adjacent to (off-site) UMDA.

Rare, Threatened, or Endangered Species. The UMDA installation is part of the critical winter range of both the bald eagle (Haliaeetus leucocephalus) and the golden eagle (Aquila chrystaetos). The former is on the federal endangered and threatened species list and both are protected under the Fish and Wildlife Coordination Act. The peregrine falcon (*Falcon peregrinus*), another federally endangered species, has been sighted in the vicinity of UMDA, and the installation is considered part of its critical habitat. One of three small habitats along the Columbia River where the long-billed curlew (*Numenius Americanus*) still breeds is located on the installation. The species is on the federal "Candidate" list. No federal or state threatened or endangered plants have been identified at UMDA[21].

The Endangered Species Act (ESA) of 1973, 16 USC §1531 *et seq*. provides a means for conserving various species of fish, wildlife, and plants that are threatened with extinction. The ESA defines an endangered species as "any species which is in danger of extinction throughout all or a significant portion of its range." In addition, the ESA defines a threatened species as "any species which is likely to become an endangered species within the foreseeable future." Further, the ESA provides for the designation of critical habitats, that are "specific areas within the geographical area occupied by the [endangered or threatened] species ... on which are found those physical or geological features essential to the conservation of the species."

Section 7 of the ESA requires consultation with the U.S. Fish and Wildlife Service to determine whether the project is likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of a critical habitat on or off the site. Since federally listed endangered and threatened species are associated with the UMDA installation, the ESA is an applicable ARAR and any action that would affect any endangered or threatened species, or adversely impact a species' critical habitat, would be subject to the requirements of the ESA.

Artifacts and Historical and Archeological Sites. There are two known historic buildings at UMDA, the headquarters building and the firehouse building. There are also two potential archeological resources at UMDA that have been tentatively identified: a portion of the Oregon Trail and a prehistoric site. None of the activities at the Miscellaneous Sites will affect these locations, so there are no ARARs for this category.

State ARARs

Wilderness Areas, Wildlife Refuges, and Scenic Rivers. There are three wildlife refuges in very close proximity to the depot: Cold Spring National Wildlife Refuge at 15 miles, Umatilla National Wildlife Refuge at 8 miles, and Irrigon State Wildlife Refuge at 12 miles. The latter of these refuges, Irrigon, is protected under state law and is considered a sensitive environment. It is one of the primary wetlands in this region and supports a major waterfowl wintering habitat. State regulations exclude or restrict certain activities in this area, including activities that deter, distract, or hinder the peaceful enjoyment of the area.

There would be no applicable ARARs for on-site actions because the UMDA itself is not located within a refuge. However, the proximity of Irrigon State Wildlife Refuge and its potential hydrological connection to UMDA cautions careful analysis of any actions that might impact that system.

Wetlands and Floodplains. Activities in a wetland involving the alteration (removal, fill, etc.) of 50 cubic yards or more are subject to approval of the Division of State Lands. Since there are no wetlands on the UMDA site, state wetlands law is not an ARAR.

2.2.2.3 Action-Specific ARARs. Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy. On-site CERCLA response actions must only comply with the substantive requirements of regulations, and not the administrative requirements [CERCLA 121(e)]. In the UMDA Federal Facility Agreement, UMDA itself is defined as the site. Therefore, in the event that the following remedial alternatives for Miscellaneous Sites are considered to take place on UMDA, none of the permitting requirements of RCRA, the Clean Air Act (CAA), etc., are considered as ARARs. The remedial actions involving treatment of contaminated soil under consideration for the Miscellaneous Sites

are: 1) incineration; 2) stabilization/solidification; and 3) soil washing. A review of potential action-specific ARARs relevant to these actions is provided in Table 2-3.

Federal ARARs - Waste

CERCLA § 121 establishes a preference for remedial actions involving treatment that permanently and significantly reduces the volume, toxicity, or mobility of the hazardous substances, pollutants, and contaminants at the site. RCRA requirements for treatment of hazardous wastes apply at a CERCLA site only if the waste is a RCRA listed or characteristic waste and the CERCLA activity constitutes treatment of RCRA hazardous waste, as defined under RCRA.

A number of remedial alternatives would result in the RCRA regulations being considered as action-specific ARARs. Under 40 CFR 261.3, any solid waste derived from the treatment, storage, or disposal of a listed hazardous waste remains that listed waste. Many of the wastes deposited at the UMDA site were deposited prior to November 19, 1980 (when RCRA was enacted), and thus were not subject to RCRA at the time of deposition. However, EPA asserts that RCRA requirements apply to any waste materials disposed of prior to 1980 when those materials are managed, treated, and/or disposed of in the present (55 FR 8762). A number of the contaminants of concern at UMDA are thus considered hazardous waste, once the process of managing, treating, and/or disposing of them begins.

A variety of activities or actions commonly performed during a CERCLA cleanup action may be sources of air emissions. These activities include incineration and handling of contaminated soil (e.g., digging and relocating soil). Many of the sources of gaseous and particulate matter emissions may be subject to federal or state regulations. In addition, control devices and some cleanup activities that increase the amount of emissions, or change the type (e.g., stack emissions from incinerators or fugitive emissions from excavation) may be considered sources subject to air emission requirements contained in the Clean Air Act (CAA) or RCRA.

Soil as Hazardous Waste. Under 40 CFR 261.3, any solid waste derived from the treatment, storage, or disposal of a listed or characteristic hazardous waste remains that listed or characteristic waste. Because the varied demolition and disposal activities that occurred throughout the Miscellaneous Sites may have involved hazardous wastes based on the characteristics of reactivity or toxicity, soils contaminated with those wastes are suspect as RCRA hazardous wastes.

The RCRA characteristic for reactivity may be considered an ARAR for soil containing explosives once that soil is excavated. This is based on the following definitions of a reactive material: it is capable of detonation or explosive reaction if it is subjected to a

Table 2-3: Action-Specific Applicable or Relevant and Appropriate Requirements (ARARs)

Medium/ Authority	Medium	Requirement	Status	Requirement Synopsis	Action to be Taken to Attain ARAR
Federal Regulatory Requirements	Air	Resource Conservation and Recovery Act (RCRA) (40 CFR 264, Subpart AA)	Relevant and Appropriate depending on concentration of emission	Regulations contain air emission standards for process vents, closed vent systems, and control devices at hazardous waste treatment, storage, or disposal facilities.	The remedial alternative shall meet the requirements of these regulations.
	Air	RCRA (40 CFR 264, Subpart O)	Potentially Applicable	Regulations for hazardous waste incinerators set forth operating requirements and performance standards.	Remedial alternatives that employ thermal destruction will comply with this regulation.
	Waste	RCRA, Identification and Listing of Hazardous Waste (40 CFR 261.3)	Applicable	Requires that wastes be analyzed to determine if they represent RCRA hazardous wastes based on established lists and hazardous waste characteristics such as reactivity and toxicity.	Waste analyses will be required of contaminated, excavated soils. These regulations will be used to define which wastes at UMDA are considered RCRA hazardous.
	Waste	RCRA, Land Disposal Restrictions (LDR) (40 CFR 268)	Applicable	Prohibits the disposal of RCRA hazardous waste in the land unless treatment standards are met or a treatability variance is obtained.	Remedial activities that involve the movement of excavated materials to a new location and placement in or on land or that generate residual hazardous wastes will trigger LDR. Any wastes subject to LDR must be treated using best demonstrated available treatment technologies for each hazardous constituent in each waste.

Table 2-3: Action-Specific Applicable or Relevant and Appropriate Requirements (ARARs) (continued)

Medium/ Authority	Medium	Requirement	Status	Requirement Synopsis	Action to be Taken to Attain ARAR
Federal Regulatory Requirements (continued)	Waste	RCRA, Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (40 CFR 264)	Applicable	This regulation establishes the minimum national standards for management of hazardous wastes for owners and operators of facilities that treat, store, or dispose of hazardous waste.	Treatment of hazardous waste may involve various forms of treatment. The design and operating standards for specific treatment units will be met: 40 CFR 264.190-264.192 (tank systems); 40 CFR 264.221 (surface impoundments); 40 CFR 264.251 (waste piles); 40 CFR 264.273 (land treatment units); 40 CFR 264.601 (miscellaneous treatment units).
	Waste	RCRA, Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities (40 CFR 264 Subpart G)	Applicable	This regulation establishes closure requirements for hazardous waste management facilities.	Remedial actions that involve on-site treatment, storage, or disposal will require closure plans.
State Regulatory Requirements	Air	Oregon Air Pollution Control Regulations (OAR Chapter 340)	Applicable	These regulations set limits on particulate and gaseous emissions.	Remedial actions will be designed and operated to comply with applicable emission limitations.
	Waste	Oregon Hazardous Waste Management Regulations (OAR Chapter 340, Divisions 100-108)	Applicable	These regulations establish state standards for closure of surface impoundments and are more stringent than the federal closure standards.	Remedial activities that involve closure of a surface impoundment on-site will comply with this regulation. All wastes will be removed prior to closure.

Table 2-3: Action-Specific Applicable or Relevant and Appropriate Requirements (ARARs) (continued)

Medium/ Authority	Medium	Requirement	Status	Requirement Synopsis	Action to be Taken to Attain ARAR
State Regulatory Requirements (continued)	Air	Oregon Air Pollution Control Regulations	Applicable	These regulations prescribe control and treatment requirements for potential sources of air contamination.	Activities involving the generation of air emissions may fall under these regulations (including soil excavation and handling and incineration of contaminated soil). Appropriate controls will be maintained during these activities to comply with these regulations.
Non-Regulatory Criteria Advisories and Guidance to be Considered	Waste	EPA Interim Policy for Planning and Implementing CERCLA Response Actions. Proposed Rule 50 FR 45933 (November 5, 1985)	To be Considered	This policy addresses the need to consider treatment, recycling, and reuse before off-site land disposal is used. Prohibits use of a RCRA facility for off-site management of Superfund hazardous substances if the facility has significant RCRA violations.	This policy will be considered prior to any off-site management of hazardous substances.

strong initiating force or if heated under confinement [40 CFR 261.23(a)(6); or it is readily capable of detonation or explosive decomposition or reaction at standard temperature or pressure [40 CFR 261.23(a)(7)].

Since it is also possible that unused pesticides (e.g., DDD, DDE, and DDT) were disposed of at UMDA, a waste analysis for RCRA P- and U-listed wastes will have to be conducted. Under 40 CFR 261.30, a solid waste is a RCRA hazardous waste if it is listed in 40 CFR 261 Subpart D (Lists of Hazardous Wastes). If any P- or U- listed wastes are found to be present in soils, the requirements of RCRA pertinent to these wastes would be an ARAR.

Further assessment of the applicability of RCRA to contaminated soils at the Miscellaneous Sites is required with respect to the toxicity characteristic because of the prevalence of heavy metals (including lead, cadmium, arsenic, barium, selenium, chromium, mercury, and silver) at the sites. If the soil exhibits the RCRA toxicity characteristic based on the Toxicity Characteristic Leaching Procedure (TCLP) (40 CFR 261.24), then that soil is a RCRA hazardous waste. For example, at Site 22, the Boiler/Laundry Effluent Discharge Site, results of the TCLP indicated that concentrations of cadmium and lead were in excess of standards. These results indicate that these soils exhibit the RCRA toxicity characteristic based on TCLP and are thus D006 (for cadmium) and D008 (for lead) listed hazardous wastes (40 CFR 261.24). In addition, these wastes may be subject to the RCRA land disposal restrictions (LDR) as described below.

For the purpose of further identifying the toxicity characteristics of contaminated soil at the Miscellaneous Sites, it will be assumed that lead concentrations of greater than 900 µg/g will cause soil to exhibit the toxicity characteristic for lead. This value was identified as a result of tests performed in the development of the FS for the UMDA Deactivation Furnace Site and reported in that FS report[22]. Concentrations of lead in excess of 900 µg/g were found in Miscellaneous Sites soils at Sites 15, 17, 19, and 32II.

Because toxicity characteristics of contaminated soil were not fully developed for all of the potential toxic contaminants, waste analyses and TCLP will be required to fully determine the toxicity characteristics and the applicability of LDR to these soils.

Land Disposal Restrictions. Hazardous waste or hazardous waste residue may be subject to restrictions on land disposal under 40 CFR 268. There are no maximum allowable residual levels for contaminants in soils under federal law. RCRA addressed land disposal of treated hazardous wastes in its land disposal restrictions in 40 CFR 268. EPA has not yet established separate treatment standards for contaminated soil, thus, it follows that until then, contaminated soils would have to meet the treatment standard for the regulated contaminating waste. However, EPA has determined that the LDRs are generally inappropriate or unachievable for soil and debris from a CERCLA response action, and recommend a treatability variance for such soils (55 FR 8760). EPA has

published guidelines for obtaining a treatability variance for soil and contaminated debris with RCRA hazardous waste (OSWER Directive 9347.3-06FS, July 1989).

LDRs do not apply to circumstances in which the waste is treated within a unit and thus would not be ARARs for actions taken within the Miscellaneous Sites. In the event that the contaminated soil or treatment residue is considered for removal from the Miscellaneous Sites for treatment or disposal, the LDR may apply.

If the hazardous waste is treated so that extract from the treated material does not exceed the TCLP toxicity characteristic threshold for any of the constituents for which it was characteristic, the material would no longer designated a hazardous waste. In terms of ARARs, the treated, formerly hazardous waste would now be a nonhazardous waste and may be disposed of on site or within a permitted solid waste facility.

Design and Operating Requirements. In general, various requirements of 40 CFR Part 264 will be applicable ARARs for remedial actions at UMDA. Any RCRA hazardous waste treatment unit (e.g., incinerator) must be designed and operated in accordance with the applicable RCRA regulations. Applicable RCRA ARARs include 40 CFR 264 Subpart I (container storage), 40 CFR 264 Subpart N (landfills), and 40 CFR 264 Subpart O (incinerators). In addition, any hazardous waste and hazardous waste residues that remain after treatment must be further treated or disposed of in accordance with RCRA. Any RCRA hazardous wastes shipped off site for treatment, storage, and/or disposal are subject to the full requirements of RCRA.

Closure Requirements. Upon completion of treatment, storage, and disposal activity, the hazardous waste treatment, storage, or disposal units must be closed and all hazardous waste and hazardous waste residues removed from the site according to the applicable regulations of 40 CFR 264 Subpart G.

Federal ARARs - Air

With regard to air emissions, any technology employed in the remedial action would have to be designed and operated so that emissions of pollutants into the air do not exceed limits established in the regulations.

Under the federal Clean Air Act National Ambient Air Quality Standards (NAAQS) program, EPA established ceilings for certain criteria pollutants, called ambient air quality standards. The six criteria pollutants are lead, nitrogen dioxide, ozone, PM-10, carbon monoxide, and sulfur dioxide. EPA has established a list of all geographic areas in compliance with the NAAQS (attainment areas) as well as those not in compliance with NAAQS (nonattainment areas). UMDA is located in a geographical area designated attainment for all six criteria pollutants. Attainment areas are subject to the Prevention of Significant Deterioration (PSD) regulations. The PSD program requires an owner or operator of a major new source or modification of an existing major source located in an

attainment area to obtain a permit before construction or modification and comply with best available control technology (BACT). The purpose of this permitting is to prevent significant degradation of air quality. The PSD regulations are considered to be not applicable to any remedial action at UMDA because emissions from such actions will not qualify as a major source.

The 1990 CAA Amendments required states to develop permitting programs for major sources and certain other sources regulated under the CAA. The deadline for state permitting programs has not been reached yet, however, CERCLA on-site actions are not subject to the administrative procedures and permit requirements.

Regulations under RCRA address air pollutant emissions from activities that may occur at UMDA (e.g., incineration). The regulations for hazardous waste incinerators (40 CFR 264 Subpart O) set operating requirements for the incinerator and performance standards for destruction and removal efficiency for principal organic hazardous constituents (PHOCs). This regulation would be considered an applicable ARAR for thermal destruction remediation technology for the treatment of contaminated soil. Proposed amendments to this regulation (55 FR 17862 [April 27, 1990]) establish a more stringent performance standard for hydrogen chloride and may constitute guidance To Be Considered (TBC).

Subpart AA of 40 CFR 264 contains air pollutant emission standards for process vents, closed-vent systems, and control devices at hazardous waste treatment, storage, and disposal facilities. These regulations are applicable to equipment associated with air or steam stripping operations that treat substances that are RCRA hazardous wastes and that have a total organics concentration of 10 parts per million by weight (ppmw) or greater. It establishes performance standards for total organic emissions from these operations. These regulations will be applicable for remedial action activities at UMDA where total organic concentrations exceed 10 ppmw. These regulations will be not be ARARs if the total organic concentration is less than 10 ppmw or if the organics are from nonhazardous sources.

State ARARs - Waste

Hazardous Waste. The Oregon Hazardous Waste Management Regulations (OAR Chapter 340 Divisions 100-108) reference the RCRA regulations for treatment, storage, and disposal, and therefore, are not repeated in this discussion. However, the closure requirements in Oregon are more stringent than the federal program in that they require the removal of all wastes, etc., at closure (the federal program gives the option of closing with wastes left in place).

State ARARs - Air

Emission Limitations. Certain sections of the Oregon Air Pollution Control Regulations (OAR Chapter 340) should be considered ARARs because the state air regulations set

emission limits for the amounts of certain pollutants emitted into the atmosphere. Applicable Oregon ARARs include those requirements that limit emissions of particulate matter (OAR 340-21) and gaseous emissions (OAR 340-22). Remedial actions such as incineration have the potential to emit contaminants into the air. Any remediation technology would have to be chosen, designed, and operated based upon its ability to comply with the applicable emission standard.

2.2.3 Allowable Exposures Based on Risk

In Section 1.2.5, Baseline Risk Assessment, a summary of the Human Health Baseline Risk Assessment was provided. This summary included the various aspects involved in the identification of current and future exposure pathways at the Miscellaneous Sites, as well as the development of risks and hazards imposed by the contaminated media at Miscellaneous Sites on future use of the area. One of the products of the RA was a comprehensive set of risk-based preliminary remediation goals (PRGs). These risk-based PRGs were presented in Table 1-9 for contaminants of concern in soil at the Miscellaneous Sites based on a number of future use scenarios. These PRGs represent the risk-based input to the development of remedial action goals.

2.2.4 Development of Remedial Action Goals

Potentially applicable remedial goals for the cleanup of contaminated soils at the Miscellaneous Sites are presented in Table 2-4. The numerical goals presented in Table 2-4 reflect risk-based remedial goals as well as background concentrations. For reference, state-established cleanup levels and certified reporting limits for the individual contaminants (as reported in the RI) are included in this table.

The ultimate goal of remedial action at the Miscellaneous Sites is to provide a mechanism for protecting human health and the environment from exposure to contaminated soils. Based on the previous discussions and the potentially applicable remedial goals presented in Table 2-4, remedial action objectives include:

- If feasible, reduce contaminant concentrations in soil to background levels or certified reporting limits; or
- Reduce the total excess cancer risk to $1x10^{-6}$ and the noncarcinogenic hazard to a hazard quotient of 1 for soil to which human exposure is likely; or
- If reduction of contaminant levels to background, certified reporting limits, or $1x10^{-6}$ total excess cancer risks is not feasible, reduce excess cancer risks to the lowest feasible level within the range of $1x10^{-4}$ to $1x10^{-6}$ with the final level to be determined based on feasibility and cost.

Table 2-4. Potentially Applicable Remedial Goals for Contaminants of Concern in Soil

Contaminant of Concern	CRLs(a) ug/g	Background(b) ug/g	Risk-Based Remedial Goals: Residential Risk-based (c) ug/g	Risk-Based Remedial Goals: Light Industrial Risk-based (d) ug/g	Risk-Based Remedial Goals: Light Industrial Risk-based (e) ug/g	Oregon NSCL(f): Residential ug/g	Oregon NSCL(f): Industrial ug/g
Antimony	3.8	3.8	110	818	818		
Barium	29.6	233	13700	861	861	20000	140000
Cadmium	3.05	3.05	127	2.75	27.5	100	1000
Calcium	59	29006	NA	NA	NA		
Chromium	12.7	32.7	19	0.413	4.13	1000	1500
Cobalt	15	15	2.74	20.2	20.2		
Copper	58.6	1300	10100	75600	75600	10000	80000
Iron	50	26233	NA	53200	53200		
Lead	6.26	500	(g)	(g)	(g)	200	2000
Magnesium	50	8585	NA	NA	NA		
Manganese	0.275	874	15200	617	617	30000	200000
Mercury	0.05	0.056	81.9	292	292	80	600
Nickel	12.6	12.6	470	10.2	102	5000	40000
Selenium	0.25	0.25	1370	10200	10200		
Silver	0.025	0.038	1370	10200	10200	1500	10000
Thallium	31.3	31.3	21.9	164	164		
Vanadium	0.775	131	1920	14300	14300		
Zinc	30.2	94	54800	409000	409000		
Cyanide	0.242	0.92	5480	40900	40900	5000	40000
Nitrate/nitrite	0.6	9.9	438000	NA	NA		
HMX	0.666	NSA	1050	2270	2270		
RDX	0.587	NSA	5.81	52	520		
Benzo(a)anthracene	0.17	NSA	0.11	0.732	7.32	0.1	1
Benzo(b)fluoranthrene	0.21	NSA	0.11	0.732	7.32	0.1	1
Benzo(k)fluorannthrene	0.66	NSA	0.11	0.732	7.32	0.1	1
Chrysene	0.12	NSA	0.11	0.732	7.32	0.1	1
Di-n-butyl phthalate	0.061	NSA	27400	204000	204000		
Fluoranthrene	0.068	NSA	10900	81800	81800	10000	80000
Phenanthrene	0.033	NSA	NA	NA	NA		
Pyrene	0.033	NSA	8210	61300	61300	8000	60000
Chlordane	0.018	NSA	0.491	3.31	33.1	0.5	4
DDD	0.008	NSA	2.66	23.8	238	3	20
DDE	0.008	NSA	1.88	168	168	2	20
DDT	0.007	NSA	1.88	12.7	127	2	20
PCB 1260	1.08	NSA	0.083	0.108	1.08	0.08	0.7

(a) Certified Reporting Limit used in RI
(b) Background Concentration established in RI
(c) Based on a Residential cancer risk of 1E-06 or an HQ of 1
(d) Based on a Light Industrial cancer risk of 1E-06 or an HQ of 1
(e) Based on a Light Industrial cancer risk of 1E-05 or an HQ of 1
(f) Oregon Numerical Soil Cleanup Levels (OAR 340-122-045(7))
(g) Action level for lead established at 500 ug/g
NA - Not available or not applicable
NSA - No standard available

Source: References 1, 4, and 17

Numerical cleanup levels corresponding to the above objectives for each of the contaminants of concern in soil at the Miscellaneous Sites are presented in Table 2-5. Risk-based numerical levels correspond to a future use of residential and a residual risk of $1x10^{-6}$ or a HQ of 1.

Although specific remedial goals were not developed as part of the Ecological Assessment (EA), it is felt that the numerical cleanup levels provided in Table 2-5 are responsive to the findings of the EA as summarized in Section 1.2.6, Ecological Assessment.

2.3 General Response Actions

2.3.1 Description

This section describes broad categories of remedial measures, called general response actions, that could be used to achieve the remedial action objectives described in Section 2.2.4, Development of Remedial Action Goals. A particular general response action might be able to be accomplished by any of several technology types. In turn, a single technology type might encompass several more specific methodologies called process options. For example, "treatment" would be a general response action, "thermal treatment" would be a technology type, and incineration or thermal desorption would be two examples of process options.

The following general response actions considered alone or in combination could potentially achieve the remedial action objectives:

- No Action
- Institutional Controls
- Containment
- Disposal
- Treatment, In Situ
- Treatment, Ex Situ

The NCP requires that "No Action" be included among the general response actions evaluated in every FS [40 CFR 300.430(e)(6)]. No Action means that no response to contamination is made, activities previously initiated are abandoned, and no further active human intervention occurs. However, natural attenuation of the chemically contaminated media may occur over time through dilution, biological degradation (of organic contaminants), and abiotic degradation (of organic contaminants). Due to the persistence of metal contaminants, little or no natural attenuation of metal-contaminated media is expected over time. The No Action response provides a baseline for comparison to the other remedial response actions.

Table 2-5. Preliminary Numerical Cleanup Levels for Contaminants in Soil at the Miscellaneous Sites Operable Unit

Contaminant of Concern	Cleanup Level ug/g	Basis
Antimony	110	Risk-based
Barium	13700	Risk-based
Cadmium	127	Risk-based
Chromium	32.7	Background
Cobalt	15	Background
Copper	10100	Risk-based
Lead	500	Risk-based
Mercury	81.9	Risk-based
Nickel	470	Risk-based
Selenium	1370	Risk-based
Silver	1370	Risk-based
Thallium	31.3	Background
Vanadium	1920	Risk-based
Zinc	54800	Risk-based
Cyanide	5480	Risk-based

Contaminant of Concern	Cleanup Level ug/g	Basis
Nitrate/nitrite	438000	Risk-based
HMX	1050	Risk-based
RDX	5.81	Risk-based
Benzo(a)anthracene	0.17	CRL
Benzo(b)fluoranthrene	0.21	CRL
Benzo(k)fluoranthrene	0.11	Risk-based
Chrysene	0.12	CRL
Di-n-butyl phthalate	27400	Risk-based
Fluoranthrene	10900	Risk-based
Pyrene	8210	Risk-based
Chlordane	0.491	Risk-based
DDD	2.66	Risk-based
DDE	1.88	Risk-based
DDT	1.88	Risk-based
PCB-1260	1.08	CRL

Notes:
- Numerical values for risk-based cleanup levels are based on risk calculations presented in the RA for future residential use with residual risk of less than 1x10-6
- CRL - Certified Reporting Limit

Source: References 4, 17, and Arthur D. Little, Inc.

Institutional controls include measures such as site access restrictions (e.g., deed restrictions and/or fencing) and land use restrictions (specifying future use such as residential or light industrial). Although potential exposure can be reduced by these means, the contaminated media are not directly remediated. As with the No Action scenario, natural recovery of organic-contaminated media might occur; however, recovery of metal-contaminated media is expected to be minimal or nonexistent.

Containment actions control or reduce migration of the contaminated materials into the surrounding environment. They might also isolate the contaminated media to reduce the possibility of exposure by direct contact. These actions may involve the use of physical barriers to block a contaminant migration pathway.

The treatment actions may include the use of biological, physical-chemical, or thermal processes to significantly reduce the toxicity, solubility, mobility, or volume of wastes. In some cases, treatment technologies are used to change the properties of the waste so as to limit the solubility or mobility of the contaminants or to prepare the waste for further treatment. Many treatment options will generate residuals or byproducts that must be disposed of with or without further treatment. The residuals or byproducts might or might not be hazardous.

2.3.2 Estimated Areas and Volumes of Contaminated Media Requiring Remediation.

In order to develop estimates of areas and volumes requiring remediation with any degree of certainty, it is necessary to examine the chemical contamination profile of each site to be remediated and compare the concentrations of contaminants of concern with the specific remedial goals presented in Table 2-5. Many of the sites at the Miscellaneous Sites involve considerable areas and the sampling performed represented a small subset of these areas. Consequently it is important to note that these estimates are preliminary in nature due to the absence of sufficient data to fully delineate the vertical and areal extent of contamination. Therefore, it is recommended that additional field screening and sampling be performed concurrently with any remedial action to further define the extent of contamination.

Despite these uncertainties, it appears as though contamination is limited to surface or near-surface soils. In addition, contamination does not appear to be a function of depth. This latter feature is likely due, in part, to sporadic grading activities that have occurred over the years at the Miscellaneous Sites.

In addition to the development of soil volumes requiring remediation in accordance with the cleanup levels provided in Table 2-5, affected areas and volumes requiring remediation have been calculated based on selected potential remedial goals provided in

Table 2-4. Specifically, additional areas and volumes have been calculated for future use of residential with a residual risk of $1x10^{-6}$, and future use of industrial with residual risk of $1x10^{-6}$ and $1x10^{-5}$.

To support the estimation of areas and volumes requiring remediation as described above, Table 2-6 is provided. This table provides the identification of sample locations (by site) and depths at which particular remedial goals were exceeded in addition to identifying the specific contaminants.

Based on the information presented in Table 2-6 and the site maps shown in Figure B-1 through B-6 in Appendix B, area and volume estimates were prepared. These estimates are presented in Table 2-7. For reference, maps illustrating the contaminated locations and area and volume calculation worksheets are provided in Appendix B.

2.4 Identification and Screening of Technology Types and Process Options

In this section, the technologies and process options associated with the general response actions discussed in Section 2.3, General Response Actions, are identified and described. These technologies and process options were subjected to a two-step screening process to eliminate inappropriate remedial options. The conduct of the screening process and its results are presented below.

The screening process was initiated with a preliminary screening to assess the response of the identified technologies and process options to technical and regulatory requirements. In this stage, those technologies and process options that were determined to be clearly inappropriate were eliminated from further consideration.

Those technologies and process options that survived the preliminary screening were then subjected to a final screening consisting of a more detailed evaluation, specifically based on the following criteria:

- Effectiveness
- Implementability
- Cost

At this stage, greater emphasis was placed on effectiveness and implementability to identify the most promising of the technologies and process options to achieve the remedial goals. Cost was a secondary consideration. Only relative capital and operating and maintenance costs were considered, with evaluations made largely on the basis of engineering judgment. Technologies and process options surviving the final screening are used to develop remedial alternatives that will be subjected to a detailed evaluation and analysis as described in Section 4.0, Detailed Analysis of Alternatives.

Table 2-6. Summary of Contaminated Soil Locations and Depths at Miscellaneous Sites Operable Unit

Site	Residential 1E-06			Lt. Industrial 1E-06			Lt. Industrial 1E-05		
	Sample No.	Depth (ft)	Cont.	Sample No.	Depth (ft)	Cont.	Sample No.	Depth (ft)	Cont.
22	22-5	0	M	22-5	0	M	22-5	0	M
	22-6	0	M	22-6	0	M	22-6	0	M
25-I	25-1	0	M						
	25-3	0	M						
	25-6	0	M						
36	36-1	0	M	36-1	0	M	36-1	0	M
	36-4	0	M	36-4	0	M	36-4	0	M
37	37-2	0	M	37-2	0	M	37-2	0	M
	37-4	0	M	37-4	0	M	37-4	0	M
47	47-3	0	M, N	47-3	0	M	47-3	0	M
	47-5	0	N						
	47-5	1.5	N						
	47-5	3	N						
48	48-2	0	N						

Depth of "0" indicates surface contamination
M - Metals
N - Nonvolatile Organics

Source: Arthur D. Little, Inc.

Table 2-7: Affected Areas and Remediation Volumes by Site and Risk Levels

	Residential 1 x 10-6			Light Industrial 1 x 10-6			Light Industrial 1 x 10-5		
Site	Area sq ft*	Volume cu yd*	Cont.	Area sq ft*	Volume cu yd*	Cont.	Area sq ft*	Volume cu yd*	Cont.
22	40000	1500	M	40000	1500	M	40000	1500	M
25-I	46000	1700	M	0	0		0	0	
36	1500	170	M	1500	170	M	1500	170	M
37	3800	420	M	3800	420	M	3800	420	M
47	2200	600	M,N	890	410	M	890	410	M
48	4700	520	N	0	0		0	0	
Total M only		3790			2500			2500	
Total N only		520			0			0	
Total N & M		600			0			0	
Grand Total	98200	4910		46190	2500		46190	2500	

M - Metals
N - Nonvolatile organic compounds
*The total affected areas and remedial volumes by site include a 25% uncertainty factor as applied in Appendix B.

Source: Arthur D. Little, Inc.

2.4.1 Identification and Screening of Technologies

The identification and screening of technologies and process options were based on a number of factors, including:

- Waste characteristics
- Site characteristics
- Technology characteristics
- Regulatory preferences

2.4.1.1 Waste Characteristics. Within the Miscellaneous Sites, soils have been found to be contaminated with metals and, to a much lesser extent, organics (explosives and pesticides). The concentrations of organics in the soils are generally very low compared to metal concentrations.

Specific waste characteristics that could potentially influence the screening process include:

Reactivity. Military regulations and prudence dictate that technologies considered for remediation mitigate the possibility of a detonation. Reactivity studies performed for USATHAMA[21] identified that a concentration of explosives in soil of 12 percent by weight is the minimum concentration at which detonation would occur. As a conservative guideline, USATHAMA has adopted a 10 percent concentration as the minimum at which reactivity would be a concern. Concentrations of explosives in soil at the Miscellaneous Sites are well below that concentration indicating that the contaminated soil does not present a concern on the basis of reactivity. However, reactivity will be addressed, as necessary, for those technologies that involve processes that concentrate or accumulate explosives.

Volatility. Technologies that rely solely on the volatility of the contaminants are not appropriate for the removal of contaminants (metals or organics) from soil at the Miscellaneous Sites. In general, the contaminants are not volatile to any appreciable degree at ambient or even moderately elevated temperatures. The contaminants may volatilize at temperatures required for incineration, but at such temperatures, volatility will not be the only mechanism involved in their removal from the soil.

Aqueous Phase Solubility. Technologies requiring removal of contaminants from soil by solubilizing them in water are not appropriate for the contaminants at the Miscellaneous Sites. The contaminants (metals, explosives, and pesticides) are generally insoluble in water.

A summary of physical and chemical properties (including vapor pressures and solubilities) for all contaminants of concern at UMDA is provided in Appendix A of this FS report.

Soil Volume Requiring Remediation. The total soil volume to be remediated may affect the selection of the best remediation technology or process option. The volumes to be used in the screening and evaluation of technologies or process options were presented in Table 2-7.

2.4.1.2 Site Characteristics. Site characteristics that influence the screening and evaluation of alternatives include:

Location and Accessibility. UMDA is located in a rural setting. Roads are located adjacent to or within one-half mile of each site to be remediated. There are no severe space limitations imposed by structures or geographic barriers.

Security. UMDA is fenced and guarded 24 hours a day. It is expected that UMDA will retain its status as a restricted-access military installation at least through the 1990s.

Proximity to Potential Receptors. Military and civilian personnel assigned to UMDA are the only reasonable nearby receptors, at this time, because of the limited access and distance from civilian populations.

Resource Availability. Electrical service is available at the Miscellaneous Sites. The site does not have natural gas service. Water can be supplied from the installation hydrant system. However, the substantial irrigation needs of the region combined with the semi-arid climate limit the acceptability of remedial action alternatives that would require large volumes of water. Lined evaporation basins located at UMDA are available to dispose of nonhazardous wastewater. These ponds were originally constructed to contain well purge water and decontamination water from the ground water monitoring program.

Surface Conditions. The Miscellaneous Sites have various covers ranging from irrigated lawns to native grasses and low brush. Some areas of the individual sites may be devoid of vegetation due to past or present activities.

Geology. A description of the site geology is given in Section 1.2.2 of this FS report. In general, surficial deposits consist predominantly of fine- to medium-grained sands, silty sands, and some gravels. The hydraulic conductivity of the soil falls within a range of 10^{-2} to 10^{-4} cm/sec. Apparent depths of ground water range from about 50 to 100 feet; fluctuations of 1 to 2 feet may be observed due to seasonal variations in precipitation.

2.4.1.3 Technology Characteristics. General technology characteristics that contribute to technology screening and evaluation include:

In Situ versus Ex Situ Treatment. For soil remediation, in situ treatment provides the advantage of implementing the technology without having to excavate the soil, thereby reducing potential for exposure as well as, in some instances, reducing costs. However, in situ technologies are limited by the need to be able to perform the treatment uniformly throughout the soil and, equally important, to provide evidence of completeness and permanence of the remediation. For most in situ technologies, effectiveness is very dependent on site-specific features such as geology, hydrology, soil characteristics, and contaminant characteristics.

On-Site versus Off-Site Treatment. The NCP specifies a preference for on-site remedies as opposed to off-site remedies. On-site remediation may eliminate the need to apply for and obtain local, state, and federal permits, although it does not preclude meeting the substantive requirements of the permit regulations. Other advantages of on-site remediation include:

- The waste generator retains greater control of the waste and residues.
- Costs of transportation are minimized.
- Potential for spread of contamination and personal exposure are reduced.

Costs of on-site treatment may be less than off-site treatment, particularly if there is a sufficient waste volume. In cases where the volume of waste to be treated is small, on-site treatment costs may be higher than off-site because of the costs required to mobilize a treatment system on-site.

Off-site treatment and disposal relieves the waste generator of the responsibility for meeting the substantive requirements for waste treatment and disposal facilities provided a properly permitted facility is chosen. However, the generator retains future liability for those wastes treated off-site. This liability extends to treatment residuals, although the generator has little control over the management or disposition of the residuals.

An additional disadvantage of off-site treatment over on-site treatment is the increase in short-term risks due to the increased potential for public exposure and environmental damage in the event of spills or mishaps during transportation of the waste off site.

2.4.2 Evaluation of Technologies and Selection of Representative Technologies

The general response actions introduced in Section 2.2, Remedial Action Objectives and potentially applicable technologies and process options are presented in Figure 2-1. The results of the preliminary screening are shown in the figure by shading those technologies

Figure 2-1: Preliminary Screening of Technologies and Process Options for Contaminated Soil

General Response Action	Remedial Technology	Process Option	Description	Screening Comments
No Action	None	None	No Action	Required for consideration by the National Contingency Plan
Institutional	Access Restriction	Deed Restriction	Restrict site use through legally binding requirements on property	Potentially applicable
		Fencing	Put fence around site	Existing
	Land Use Restriction	Residential	Property use will be restricted to residential with no agricultural use	Potentially applicable
		Light Industrial	Property use will be restricted to light industrial	Potentially applicable
		Military	Property use will be restricted to military	Potentially applicable
Containment	Capping	Engineered Cap	Install single or multilayered cap of materials such as clay, asphalt, concrete, and/or synthetic membrane	Potentially applicable
	Surface Control	Clean Soil Cover	Install layer of clean soil over contaminated area	Potentially applicable
		Vegetation	Plant vegetation over contaminated area	Potentially applicable

☐ Potentially applicable technology

▒ Eliminated from further consideration

Figure 2-1: Preliminary Screening of Technologies and Process Options for Contaminated Soil (continued)

General Response Action	Remedial Technology	Process Option	Description	Screening Comments
On-Site Disposal	Landfilling	Existing Landfill	Dispose of contaminated soil and/or treatment residues in existing landfill	Potentially applicable
		New Landfill	Dispose of contaminated soil and/or treatment residuesin new on-site landfill	Potentially applicable
Treatment, In-Situ	Biological	Aerobic	Destruction of contaminants by aerobic microorganisms	Not applicable due to metal contaminants
		Anaerobic	Destruction of contaminants by anaerobic microorganisms	Not applicable to metal contaminants
	Physical-Chemical	Soil Washing	Leach contaminant from soil with a water and detergent solution	Not applicable to metal contaminants
		Solidification/Stabilization	Immobilize contaminants using cement, pozzolans, and/or setting agents	Not applicable due to lack of proof of effectiveness or permanence of remedy
		Vacuum Extraction	Place soil under vacuum to enhance organic volatilization	Not applicable to nonvolatile contaminants
	Thermal	Radio Frequency Heating	Volatilize contaminants by heating the soil with radio frequency waves	Not applicable to nonvolatile contaminants
		Thermal Stripping	Volatilize contaminants by heating the soil	Not applicable to nonvolatile contaminants
		Vitrification	Encapsulate contaminants by glassifying soil at high temperatures	Not applicable due to lack of proof of effectiveness or permanence of remedy

☐ Potentially applicable technology

▒ Eliminated from further consideration

Figure 2-1[illegible] Preliminary Screening of Technologies and Process Options for Contaminated Soil (continued)

General Response Action	Remedial Technology	Process Option	Description	Screening Comments
Treatment, Ex Situ	Biological	Slurry-Phase Treatment	Degrade contaminants in a slurry reactor	Not applicable to soil contaminated primarily with metals
		Composting	Degrade contaminants by processing soil with amendments, fertilizers, and water	Not applicable to soil contaminated primarily with metals
	Physical-Chemical	Solidification/Stabilization	Immobilize contaminants in soil using cement, pozzolans, and/or setting agents	Potentially applicable
		Soil Washing	Remove contaminants from soil by chemical and/or physical means	Potentially applicable to reduce soil volume requiring treatment
	Thermal	Glassification	Encapsulate contaminants by glassifying soil at high temperatures	Potentially applicable
		Incineration	Decompose and volatilize contaminants at high temperatures	Potentially applicable
		Thermal Stripping	Volatilize contaminants from soil by low temperature thermal processing	Not applicable to nonvolatile contaminants
	Off-Site	Treatment or Disposal	Treat or dispose of contaminated soil at a RCRA-approved facility	Potentially applicable

Potentially applicable technology

Eliminated from further consideration

and process options that are clearly not applicable to remediation of the Miscellaneous Site soils. The rationale supporting the elimination of these technologies and process options is summarized in the column on the right.

Technologies and process options were initially screened by assessing whether or not they were conceptually viable with respect to technical capabilities and the screening criteria presented in Section 2.4.1, Identification and Screening of Technologies. A brief discussion of the important parameters and rationale behind particular screening decisions is provided below.

It is important to note that the technologies and process options surviving the preliminary screening (as well as the final screening) will be incorporated into remedial alternatives that will then be subjected to a detailed analysis. These remedial alternatives may consist of a single technology or process option or may include a series of the retained options.

2.4.2.1 Preliminary Screening. *No Action.* The No Action alternative does not reduce human exposure or contaminant toxicity, mobility, or volume. However, as required by the NCP, it will be carried through subsequent screening and analysis as a viable option where appropriate to provide a baseline reference point for review and comparison of various alternatives.

Institutional Controls. The placement of institutional controls such as access restrictions and/or land use restrictions on the future use of the Miscellaneous Sites is a means of minimizing or preventing human exposure to contaminants. However, such restrictions do not reduce the toxicity, mobility, or volume of contaminants.

The use of access restrictions such as the imposition of deed restrictions or fencing will limit future use possibilities for the site. Despite this limitation, the absence of future use plans for UMDA in general and the Miscellaneous Sites specifically, impact the decision to carry access restrictions to the next stage of evaluation.

Land use restrictions comprise an additional aspect to institutional controls. The options under consideration include:

- Restriction of future property use to residential only with no agricultural use permitted
- Restriction of future property use to light industrial only

Because of the uncertainties associated with future use scenarios at this time both options will be carried over into the next phase of the evaluation.

Containment. Waste containment technologies are generally intended to minimize exposure to contaminated soil and/or to reduce the mobility of contaminants to prevent

their migration. The toxicity or volume of the contaminants is not reduced. Containment options considered include the use of surface controls such as a clean soil cover and/or vegetation as well as capping the site with an engineered cap.

Surface controls are relatively expensive and low-technology approaches to containment. Such controls include applying a clean soil layer over the contaminated soil and/or planting vegetation over the contaminated area. Due to the arid and exposed conditions at UMDA, a clean soil layer alone would provide an expedient, but short-term means of containment due to wind erosion. For this reason, use of a clean soil cover alone is eliminated from further consideration. Covering the clean soil with vegetation would decrease the potential for erosion due to wind by increasing the stability of the surface environment. A combination of clean soil cover and revegetation is retained for further consideration as a potentially effective means of controlling the wind dispersion of contaminants.

In many cases, vegetation alone would adequately decrease the potential for wind dispersion of surface contaminants. However, the native vegetation of UMDA is sparse and not well-suited for erosion control. For this reason, vegetation as the sole means of surface control is eliminated form further consideration.

A higher-technology approach to containment is offered by the use of engineered caps over the contaminated soils. Engineered caps may be constructed from a variety of materials, including asphalt, concrete, clays, sands, and soils. These caps may consist of a single layer or may be composed of multiple layers. Single layer caps will generally require continuous and long-term monitoring to ensure that their integrity is retained. Multiple layer caps are more desirable for uses requiring long-term protection of human health and the environment. For the purposes of longevity of cover and insurance of long-term maximum protection, a multiple layer cap consisting of a clay layer covered by clean soil will be retained for further evaluation.

On-Site Disposal. The use of on-site disposal of contaminated soil and/or treatment residues may be accomplished using the existing active landfill or, alternatively, by constructing a new engineered landfill on site for the specific purpose of disposal of these materials. The toxicity or volume of the contaminants is not reduced by implementation of these options; however, they may allow for greater control of the potential spread of contamination than if the contaminated soil were to be left in place.

Consideration of the use of on-site disposal for the contaminated soil is impacted by LDR prohibiting the disposal of soil exhibiting the characteristic of toxicity. As described in Section 2.2.2.3.1, Soil as Hazardous Waste, some Miscellaneous Sites soils containing lead (sites 22 and 47) potentially exhibit the toxicity characteristic and, as such, land disposal of these contaminated soils may be prohibited. A review of contamination data developed in the RI indicates that the toxicity characteristic may be exhibited by over half

of the total contaminated soil volume at the Miscellaneous Sites due to the presence of lead. The use of on-site disposal for untreated contaminated soils would be limited to those soils that do not exhibit any hazardous characteristic and would require extensive testing to ensure that the soils to be placed on-site are not hazardous. On-site disposal in either the existing active landfill or in a new engineered landfill is retained for consideration for the disposal of proven nonhazardous soils only.

If it can be shown that the contaminated soil that exhibits the hazardous characteristic can be treated so that it no longer exhibits that characteristic, then that treated material is no longer subject to LDR and can be landfilled. Use of on-site landfills (existing active landfill or a new landfill) for the disposition of residuals resulting from the treatment of contaminated soil is retained for further consideration because of the technical feasibility of on-site disposal and its potential to reduce exposure and migration of contamination.

In Situ Treatment. In situ options considered include treatment by biological, physical-chemical, and thermal methods.

- Biological In Situ Treatment. The use of aerobic or anaerobic microorganisms to degrade contaminants in soil is a potentially effective method for reducing the toxicity and mobility of organic compounds in soil. However, the use of microorganisms in situ has not been demonstrated to affect the mobility or toxicity of metals. Since the contaminated soils at the Miscellaneous Sites contain metals, this option has been dropped from further consideration for all three contaminant/soil matrices.

- Physical-Chemical In Situ Treatment. Physical-chemical treatment techniques that may be employed in situ include:

  - Soil washing is a method in which contaminants are leached from the soil with a water and detergent solution. This technique has been proven to a greater extent with soil that has been excavated. Because the contamination at this site is relatively shallow (less than 15 feet below the surface), there is no particular advantage to the use of the processes in situ. In situ applications of soil washing are therefore eliminated from further consideration.

  - Solidification/stabilization involves the mixing of specialized additives or reagents with contaminated soil to physically or chemically reduce the solubility or mobility of contaminants in the soil. Stabilization typically refers to techniques that chemically modify the contaminant to form a less soluble, mobile, or toxic form without necessarily changing the physical characteristics of the waste. Solidification refers to a technique for changing the physical form of the waste to produce a solid structure in which the contaminant is mechanically trapped. Many stabilization and solidification processes overlap and therefore are often described

as one technology. Although these processes have reportedly been demonstrated with a variety of contaminants (primarily metals); their long-term effectiveness and permanence is unknown. The technology has been proven to a greater extent with soil that has been excavated. Because the contamination at this site is relatively shallow (less than 15 feet below the surface), there is no particular advantage to the use of the processes in situ. In situ applications of solidification/stabilization are therefore eliminated from further consideration.

- Vacuum extraction, in which the soil is placed under vacuum to enhance the volatilization of contaminants from the soil. Since the contaminants of concern at the Miscellaneous Sites are nonvolatile, this alternative is dropped from further consideration for all three contaminant/soil matrices.

- Thermal In Situ Treatment. Two thermal techniques for in situ soil remediation are radio frequency heating and thermal stripping. Both of these techniques involve heating soil, thereby enhancing volatilization of contaminants for their removal from the soil. Since the success of these methods depends on the volatilization of the contaminants, they are clearly not appropriate for the nonvolatile contaminants at the Miscellaneous Sites. Thermal in situ treatment relying on the volatilization of contaminants is therefore eliminated from further consideration for all three contaminant/soil matrices.

A third thermal technique that can be employed in situ is vitrification, a method whereby contaminants are immobilized in place through encapsulation in glassified soil. This technique typically involves the addition of chemicals to contaminated soil followed by the application of electrical energy to produce a solidified (glassified) soil. This technology has not been successfully demonstrated on a large scale and has not been demonstrated on any scale with explosives. In addition, the success of in situ vitrification relies on the assurance that the vitrified mass is continuous throughout the contaminated site thereby eliminating the potential for future leaching or movement of contaminants from the site.

This ability has not yet been demonstrated. Because of insufficient demonstration of the effectiveness of vitrification as well as uncertainties about its permanence this technology is eliminated from further consideration for the Miscellaneous Sites.

- Ex Situ Treatment. In ex situ treatment, contaminated soil is excavated from the site and subjected to treatment on site or off site. Options for treatment include processes employing biological, physical-chemical, or thermal methods.

- Biological Ex Situ Treatment. Potential technologies employing biological processes to treat contaminated soil ex situ include slurry-phase treatment and composting.

- Slurry-phase treatment involves diluting the contaminated soil with water and feeding the resulting slurry to a system containing bacteria. Although slurry phase treatment was considered conceptually viable in a 1990 evaluation, effectiveness has not yet been demonstrated[23]. This technology is therefore eliminated from further consideration for contaminated soil remediation at the Miscellaneous Sites.

- Composting is an innovative method for the treatment of soils contaminated with organic compounds, including explosives. Composting is commonly used for treating sewage sludge, municipal solid wastes, and yard wastes. Recently it has been examined for use in remedial actions involving the treatment of contaminated soil. In order to achieve composting conditions, contaminated soils must be altered to produce a compostable matrix. Usually this is accomplished by adding an amendment mixture to the contaminated soil. This amendment mixture typically consists of a bulking agent to improve the physical characteristics of the soil and a carbon source for ensuring the sustenance of active microbial populations. The reliance on amendments is a potential disadvantage to composting due to the increase in volume (as much as 200%) of the contaminated media.

Composting has been demonstrated for site-specific applications involving the treatment of soil contaminated with explosives. Treatability studies have shown that it can effectively reduce contaminant concentrations and soil toxicity by greater than 90 percent[24,25].

The effect of composting on metal-contaminated soil has not been determined. Although it is suspected that composting may result in immobilization of the metals, it has not been demonstrated or proven on any scale[26]. There is the potential that the levels of metals in the Miscellaneous Sites soils may prove toxic to biological activity. The use of composting as a pretreatment to remove organic contaminants prior to subsequent treatment to remove metals is not practical due to the significant increase in volume resulting from the addition of soil amendments. For these reasons, the feasibility of using composting to treat these soils is questionable and thus will not be considered further in this analysis.

- Physical-Chemical Ex Situ Treatment. Physical-chemical techniques that can be employed to treat excavated soil include solidification/stabilization and soil washing.

  - Solidification/stabilization involves the mixing of specialized additives or reagents with contaminated soil to physically or chemically reduce the solubility or mobility of contaminants in the soil. Stabilization typically refers to techniques that chemically modify the contaminant to form a less soluble, mobile, or toxic form without necessarily changing the physical characteristics of the waste.

Solidification refers to a technique for changing the physical form of the waste to produce a solid structure in which the contaminant is mechanically trapped. Many stabilization and solidification processes overlap and therefore are often described as one technology. These techniques have been demonstrated to be implementable to treat soil contaminated with metals and therefore have potential application as a remedial alternative for soils at the Miscellaneous Sites. The effect of solidification/ stabilization on organics has not been as well demonstrated. In some cases, organics may even negatively impact the quality of the treated product. Treatability studies would be required to determine the effect of any organics on the treated matrix as well as to demonstrate the feasibility of the process on Miscellaneous Sites soils in general and develop optimum operating parameters. Despite the uncertainties with respect to organic contamination, it should be noted that the level and frequency of organic contamination at the Miscellaneous Sites is very low compared to metal contamination. Because of the potential for immobilization of metal (and perhaps organic) contaminants at the Miscellaneous Sites, solidification/ stabilization is retained in this evaluation for further consideration.

– Soil washing involves the removal of contaminants from soil by chemical and/or physical means. It is typically employed as one of a series of unit operations. Soil washing results in the transfer of contaminants from one medium (soil) to another (liquid) thereby requiring additional treatment. Specific processes involved in soil washing include:

- Physical separation of contaminated particles by washing with water, agitation, and particle classification. When used on contaminated soil, this process makes use of the tendency of contaminants to concentrate in the finer particles (or fines) of soil because of the relatively large surface area available per unit volume of fine particles compared to that of the larger particles, thereby leaving the larger particles relatively contaminant-free. Ideally, separation of the two ranges of particle sizes then allows for a significant reduction in soil volume to be treated.

- Solvent extraction using an appropriate solvent to solubilize the contaminants that are then removed from the soil with the solvent.

- Acid extraction making use of the solubility of metals in acid to remove them from soil. An acidic aqueous solution is added to the excavated soil, the metals are dissolved into the solution, and the metal-laden solution is separated from the soil and subjected to further treatment.

The soil washing processes described above may be used alone or in combination depending on the contaminant(s) to be removed from soil.

Soil washing using water to physically remove contaminants from soil has been demonstrated effective in specific applications[27,28]. Application of the technology has the potential to substantially reduce the volume of contaminated soil requiring further treatment or disposal. The soil washing technology is reportedly moderately to marginally effective for the removal of pesticides from soil. In addition, bench-scale studies conducted by USATHAMA indicate that removal efficiencies of explosive compounds are generally poor [31,32].

Solvent extraction has been demonstrated on a laboratory scale to be an effective means of removing explosives and pesticides contaminants from soil[32]. Solvent extraction is not applicable to metals in soil. A study conducted by USATHAMA used acetone to remove explosives from soil, since all of the explosives of interest were either soluble or easily dispersed in acetone at room temperature. Initial concentrations of explosives in the soil ranged from 1,200 μg/g to 420,000 μg/g. Final concentrations were 6 to 17 μg/g, for an extraction efficiency of greater than 99.5 percent.

The limitations of solvent extraction arise upon consideration of the fate of the extract. In the study referenced above, the acetone was recovered by boiling off the moisture, leaving a small amount of acetone with the explosives to maintain them in a wet state and reduce the potential for detonation. While this reduces the volume of contaminated media, it is not a final treatment. The study concluded by indicating that the acetone/explosives moisture could then be incinerated. However, the production of a concentrated explosives mixture, particularly entrained in a flammable solvent, is generally unacceptable because of the stringent requirements imposed on facilities that process detonatable concentrations. In addition, it is unlikely that a commercial incinerator would be willing to accept a potentially explosive mixture.

Acid extraction has been used in the metallurgical industry for the extraction of metals from various media to allow for their recovery [32]. The major problem with this technology is the generation of large quantities of acid waters contaminated with metal compounds. There is no apparent application of acid extraction for the removal of explosives or pesticides.

Both solvent and acid extraction can be involved procedures employing a number of unit processes. They rely on the transfer of contaminants from one medium (soil) to another (solvent or acid), thereby generating another waste stream requiring treatment. In addition, safety considerations associated with the storage of large quantities of acids and solvents (such as acetone) required for the processes are significant.

Soil washing using aqueous solutions to physically separate contaminants and fines from soil is retained for further evaluation due to its potential to reduce the volume of contaminated soil requiring further treatment or disposal. Solvent and acid extraction are eliminated from further consideration for a number of reasons, including their reliance on large volumes of acids and solvents and the generation of acid and solvent waste streams that require subsequent treatment.

- Thermal Ex Situ Treatment. Alternatives considered for the thermal treatment of excavated soil include glassification, incineration, and thermal stripping.

  - Glassification makes use of well-established technology for the melting of glass. Glassification involves high temperature (typically 2200°F) treatment of contaminated solids for the purpose of destroying organic contaminants and immobilizing metals (and most other inorganics) contaminants in a glass residual product form. Organic components of wastes are thermally oxidized. Offgases are vented through a scrubber. Ash containing inorganic components is entrapped in the glass. The technology has been shown to be effective with a variety of organic compounds and metals[33]. Glassification has not been demonstrated for use with explosives; however, extrapolation of results of incineration of explosive-contaminated soil at temperatures of 1500 to 1800°F indicate that explosives would most likely be successfully oxidized at glassification temperatures [34]. Glassification is retained for further consideration based on its potential to successfully treat all contaminant/soil matrices.

  - Incineration involves the oxidation of organic compounds at high temperatures. Incineration has been widely demonstrated as an effective means of remediating organic-contaminated soils including explosives and pesticides. Metals in the incinerator feed may either be contained in the incinerator offgas and subsequently separated from the offgas in air pollution control equipment or may be retained in the incinerator ash residue. Because of the demonstrated applicability of incineration for soil containing organic contaminants, it is retained for further evaluation.

  - Thermal stripping involves heating soil at low temperatures, thereby enhancing volatilization of contaminants for their removal from the soil. Since the success of thermal stripping depends on the volatilization of the contaminants at low temperatures, it is clearly not appropriate for the nonvolatile contaminants at the Miscellaneous Sites. Thermal stripping is therefore eliminated from further consideration.

Off-Site Treatment and/or Disposal. Although the NCP specifies a preference for on-site remedies, there are certain circumstances in which off-site treatment and/or disposal may be preferable; particularly for smaller waste volumes. The potential for some of the

Miscellaneous Sites soils to exhibit the toxicity characteristic due to the presence of lead (and cadmium), would require that implementation of this option involve the segregation of soils according to their toxicity characteristic. Soil exhibiting the toxicity characteristic would require treatment prior to disposal. Other soils could be disposed of as non-hazardous wastes.

Because of the potential for off-site treatment and/or disposal to be easily implemented and cost effective, this alternative is retained for further consideration for the contaminated soils at the Miscellaneous Sites.

2.4.2.2 Final Screening of Technologies. General response actions, technologies and process options remaining after the preliminary screening are presented in Figure 2-2. These technologies and process options have been evaluated in greater detail below according to the criteria of effectiveness, implementability, and cost. Brief descriptions of each of these criteria are presented below.

The effectiveness of the process options was evaluated based on:

- The potential effectiveness of the process option in handling the estimated areas or volumes of media and meeting the remedial action objectives
- The potential impacts to human health and the environment during the construction and implementation phase
- The degree to which the process is proven and reliable with respect to the contaminants and conditions at the site

The implementability of the process option encompasses both the technical and administrative feasibility of implementing the option. Technical implementability was the major criterion used for screening the process options in the preliminary screening to eliminate those that were clearly not applicable to the contaminants or the contaminated media. This final screening places greater emphasis on the institutional aspects of implementability including the ability to obtain necessary permits for off-site actions; the availability of treatment, storage, and disposal services; and the availability of skilled workers to implement the technology.

The cost evaluation plays a limited role in the screening of process options. The costs that are developed are relative in nature and not detailed. These costs are usually developed based on engineering judgement, and each process is evaluated as to whether costs are high, medium, or low with respect to the other process options.

2.4.2.2.1 No Action. The No Action response action involves no technology, requires no implementation, is not effective in reducing toxicity, mobility, or volume of the waste, and incurs no direct cost. The presence of metal contaminants in the soil is expected to be persistent; little or no natural recovery will occur. Some natural

Figure 2-2: Final Screening of Technologies and Process Options for Contaminated Soil

General Response Action	Remedial Technology	Process Option	Description	Screening Comments
No Action	None	None	No Action	Required for consideration by the National Contingency Plan
Institutional	Access Restriction	Deed Restriction	Restrict site use through legally binding requirements on property	Potentially applicable
		Fencing	Put fence around site	Existing
	Land Use Restriction	Residential	Property use will be restricted to residential with no agricultural use	Potentially applicable
		Light Industrial	Property use will be restricted to light industrial	Potentially applicable
		Military	Property use will be restricted to military	Potentially applicable
Containment	Capping	Engineered Cap	Install single or multilayered cap of materials such as clay, asphalt, concrete, and/or synthetic membrane	Potentially applicable
	Surface Control	Clean Soil Cover	Install layer of clean soil over contaminated area	Potentially applicable
		Vegetation	Plant vegetation over contaminated area	Potentially applicable

☐ Potentially applicable technology

▨ Eliminated from further consideration

Figure 2-2: Final Screening of Technologies and Process Options for Contaminated Soil (continued)

General Response Action	Remedial Technology	Process Option	Description	Screening Comments
On-Site Disposal	Landfilling	Existing Landfill	Dispose of contaminated soil and/or treatment residues in existing landfill	Potentially applicable
		New Landfill	Dispose of contaminated soil and/or treatment residuesin new on-site landfill	Potentially applicable
Treatment, Ex Situ	Physical-Chemical	Solidification/Stabilization	Immobilize contaminants in soil using cement, pozzolans, and/or setting agents	Potentially applicable
		Soil Washing	Physically concentrate contaminants by water washing and particle classification	Potentially applicable
	Thermal	Glassification	Encapsulate contaminants by glassifying soil at high temperatures	Not applicable due to high capital cost and low soil volume
		Incineration	Decompose and volatilize contaminants at high temperatures	Potentially applicable
	Off-Site	Treatment or Disposal	Treat or dispose of contaminated soil at a RCRA-approved facility	Potentially applicable

Potentially applicable technology

Eliminated from further consideration

degradation of organics might occur, however the rate of recovery is expected to be slow. Since the metals are the predominant contaminants at the Miscellaneous Sites, the natural degradation of the organic contaminants will have little effect on the risks and hazards associated with the site. The No Action alternative is included as a requirement of the NCP and provides a baseline for comparison with the other technologies.

2.4.2.2.2 Institutional Controls. Access restrictions and land use restrictions have been carried forward to this stage of screening.

- Effectiveness. Although institutional controls alone provide a certain degree of effectiveness with respect to protecting human health by reducing the potential for exposure, they do nothing to reduce the toxicity, mobility, or volume of contaminants and therefore offer little improvement in protecting the environment over the long-term. The imposition of these alternatives may limit future use possibilities for the site.

- Implementability. Institutional controls such as access restrictions and land use restrictions are easily implemented. The sites are currently subjected to access restrictions and control.

- Cost. Despite the fact that the institutional controls themselves will be of minimal cost to implement, there will be costs incurred with the long-term maintenance of the controls as well as loss of the cost benefit possibly resulting with the sale of the site by the Army.

- Summary. Institutional controls alone will not satisfy the regulatory preferences for remedies that "utilize permanent solutions." However, the use of institutional controls at the Miscellaneous Sites are retained for further consideration because of the uncertainties associated with future use of the UMDA site.

2.4.2.2.3 Containment - Engineered Cap. Covering areas of contamination using an engineered cap is a technically feasible remedial option under the containment general response action. An engineered cap employed at the Miscellaneous Sites would consist of a layer of clay covered by a layer of soil, which would allow for revegetation to provide an additional level of surface stability and protection.

- Effectiveness. Capping is effective at limiting infiltration due to rainfall, providing a barrier that minimizes the potential for contact and exposure, and providing stability to the contaminated surface to limit the potential for wind dispersion of contaminants. Use of a multiple layer cap such as a clay/soil cap provides long-term assurance that the contaminated surface is stable and contained. Capping does not decrease the toxicity or volume of the contaminants.

- Implementability. From a technical standpoint, capping could be easily implemented at the areas of contamination. Equipment required for capping is readily available. The use of a cap would require maintenance and monitoring to ensure long-term integrity of the cap. Land use restrictions would be required.

- Cost. The cost to install an engineered cap using layers of clay and soil and planting vegetation would cost approximately $0.80 per square foot of area to be covered or approximately $63,000 at the Miscellaneous Sites.

- Summary. The use of an engineered cap with vegetation would provide adequate protection of human health and the environment provided that the cap is maintained and monitored over the long term and some degree of future land use restrictions are applied. The cost of installing such a cap would not be prohibitive. A cap, however, does not provide for the reduction of volume of contaminated materials or does not reduce the toxicity of the contaminants. Given the possibility that future land use restrictions will be applied at the Miscellaneous Sites, the use of an engineered cap with vegetation is retained for further analysis.

2.4.2.2.4 Containment - Soil Cover/Vegetation. Covering areas of contamination with a layer of clean soil and vegetation is a second feasible containment option. It is assumed that suitable soil cover material would be obtained from uncontaminated areas at UMDA.

- Effectiveness. A soil cover is less effective than an engineered cap at limiting infiltration. However, since potential evapotranspiration rates in the region (32 inches per year) exceed precipitation rates (8 to 9 inches per year), a cover of clean soil would possibly reduce the amount of precipitation reaching underlying contaminated soil. A clean soil cover would also reduce the potential for direct contact with contaminated soil, both by humans and by the root systems of plants. The effectiveness of the soil cover in stabilizing the contaminated surface and preventing wind dispersion of contaminants would be enhanced by the use of vegetation. The use of a soil cover with vegetation would not reduce the toxicity or volume of contaminants.

- Implementability. Placing a soil cover over areas of contamination would be relatively simple. There are several areas of undisturbed, uncontaminated soil on the UMDA installation from which materials could be obtained. Equipment used to install the soil cover is standard and readily available. As with an engineered cap, the use of a soil cover would require maintenance and monitoring to ensure long-term integrity of the cover. Land use restrictions would be required.

- Cost. Installation of a soil cover and vegetation would cost approximately $0.55 per square foot of area to be covered or approximately $43,000 for the Miscellaneous Sites.

- Summary. The use of a soil cover with vegetation would provide a certain degree of protection of human health and the environment provided that the cover is maintained and monitored over the long term and future land use restrictions are applied. The cost of installing such a cover would be low. A soil cover, however, does not provide for the reduction of volume of contaminated materials or does not reduce the toxicity of the contaminants. Given the possibility that future land use restrictions will be applied at the Miscellaneous Sites, the use of a soil cover with vegetation is retained for further analysis.

2.4.2.2.5 On-Site Disposal. On-site disposal options to be considered in this phase of the screening include the disposal of nonhazardous contaminated soil and/or nonhazardous solid treatment residual. Disposal would be in either the existing UMDA active landfill or in a new engineered landfill to be constructed on site.

- Effectiveness. The primary benefit to relocation of the nonhazardous contaminated soils to an on-site landfill would be the increased control over the soils to minimize the potential for exposure and release to the environment. Landfilling of the contaminated soils that exhibit hazardous characteristics would not be possible without treatment to eliminate the hazardous characteristic. Once it is proven that the hazardous soils are rendered nonhazardous, then landfilling the treatment residuals provides an effective means of controlling exposure to and release of the residuals.

- Implementability. Disposal of nonhazardous materials in the on-site active landfill is easily implemented. Disposal of soil that is hazardous is complicated by the need to treat the soil prior to disposal.

- Cost. On-site disposal by utilizing the active landfill is a relatively low cost alternative with costs reflecting the excavation, hauling, dumping, and covering of the nonhazardous material to total of which is estimated at approximately $4 per cubic yard. This cost includes only the disposal costs; it does not include soil treatment costs that are considered in treatment-specific option or final closure costs, in accordance with requirements of its permit and ODEQ solid waste regulations and guidance, which are included in the active landfill closure costs.

- Summary. The on-site disposal of contaminated soils and/or treatment residues will be subject to regulatory and Army approval. In general, however, on-site disposal is a feasible and potentially low-cost option for disposition of the contaminated soils

and/or treatment residues at the Miscellaneous Sites. Because of the feasibility and potential low cost of on-site disposal, this option will be retained for further analysis.

2.4.2.2.6 Ex Situ Treatment - Solidification/Stabilization. Technologies and process options falling under solidification/stabilization response actions are those that limit the solubility or mobility of contaminants within the soil matrix, with or without changing the physical characteristics of the matrix. They include stabilization, solidification/stabilization, and sorbent solidification. Solidification alone generally implies that the matrix is transformed into a solid monolith for the primary purpose of structural integrity. Stabilization generally implies that contaminants within the matrix become physically or chemically bound.

- Effectiveness. Solidification/stabilization would be accomplished by mixing the soil with various materials such as portland cement, certain pozzolans, silicates, thermoplastics, and/or bitumens to form a solid matrix that incorporates the combinations of contaminants. The contaminants might or might not be chemically bound to constituents within the matrix. Site-specific treatability studies have not been performed, so the chemistry and the effective reduction in contaminant mobility cannot be evaluated. Solidification/stabilization would not reduce the toxicity or volume of the waste.

- Implementability. Solidification/stabilization may be relatively easily implemented. There are a number of vendors of turnkey systems for on-site solidification/stabilization. Equipment used is typically mobile and easily mobilized.

- Cost. The cost of solidification/stabilization varies greatly with the type of process used. Estimated costs for treatment of contaminated solids by solidification/stabilization using portland cement, pozzolans, and/or silicates a typically are in the range of $50 to $75 per cubic yard.

- Summary. As a potentially effective (in reducing the mobility of contaminants), easily implemented, and typically low-cost technology, solidification/stabilization is retained for further evaluation. Treatability studies would be required to determine the effectiveness of solidification/stabilization with the contaminant/soil matrices at the Miscellaneous Sites.

2.4.2.2.7 Ex Situ Treatment - Soil Washing. The physical separation of contaminated particles by washing with water, agitation, and particle classification is a potentially effective means to treat contaminated soil. When used on contaminated soil, this process

makes use of the tendency of contaminants to concentrate in the finer particles (or fines) of soil leaving the larger particles relatively contaminant-free. Ideally, separation of the two ranges of particle sizes then allows for a significant reduction in soil volume to be treated.

- Effectiveness. The effectiveness of soil washing to physically concentrate contaminants by particle size classification is very dependent on specific soil and contaminant characteristics. Proof of its effectiveness for any given application would require feasibility/treatability testing. Soil washing using water to physically remove metals from soil has been demonstrated effective in specific applications [27,28]. Application of the technology has the potential to substantially reduce the volume of contaminated soil requiring further treatment or disposal. The soil washing technology is reportedly moderately to marginally effective for the removal of pesticides from soil. However, bench-scale studies conducted by USATHAMA indicate that removal efficiencies of explosive compounds are generally poor [29,30].

- Implementability. Equipment for on-site soil washing is readily available, mobile, and capable of processing contaminated soil at a wide range of throughputs [28]. The technology relies on the use of recycled water so there are no concerns regarding the storage and use of other extraction agents such as solvents or acids. Since the water is recycled, there are no concerns with the use of excessive amounts of water since it is a valuable resource at UMDA.

- Cost. The cost of soil washing to reduce the volume of contaminated soil is dependent on the total volume to be treated. A cost analysis performed for USATHAMA indicates that representative unit costs to treat soil at volumes required for remediation of Miscellaneous Sites soils are near $140 per cubic yard of soil[28]. This analysis also included the comparison of costs associated with the solidification/stabilization and soil washing to identify the volume of soil at which soil washing as a pretreatment was economical. The results indicate that the cost effectiveness of soil washing is in doubt at volumes of approximately 5,000 cubic yards and less[28]. Since soil volumes at the Miscellaneous Sites are less than this, soil washing, if determined effective, may not be attractive from a cost standpoint.

- Summary. Soil washing to reduce the volume of contaminated soil by concentrating the contaminants may be technically feasible and cost effective. Its effectiveness would require demonstration by feasibility/treatability testing. The process is relatively easily implemented. Because of the potential for effectiveness as well as implementability, soil washing as a pretreatment to reduce the contaminated volume is retained for detailed analysis.

2.4.2.2.8 Ex Situ Treatment - Incineration. A variety of thermal technologies exists for the treatment of solids containing organic contaminants. These techniques thermally oxidize or pyrolyze combustible pollutants at elevated temperatures to produce the combustion products carbon dioxide and water. Other elemental constituents such as nitrogen, halogens, phosphorus, and sulfur are typically converted to acidic vapors. If the incinerated material contains metals, they may be retained in the ash, retained as particulates in the air pollution control system, or may be volatilized and released to the atmosphere.

Advantages of thermal treatment of wastes are:

- Toxic organic components are permanently converted to harmless or less harmful compounds.
- Thermal destruction of organic-contaminated material may be an ultimate treatment in itself, requiring no further treatment of residuals.

The most commonly used incineration process for the on-site treatment of contaminated soil is the rotary kiln incinerator. With this incinerator, waste is combusted in a refractory-lined kiln that is heated by burning fossil fuels. Exhaust gases pass through a secondary combustion chamber (afterburner) and air pollution control (APC) equipment. Minimal feed preparation is required. The primary residues generated are solid from the combustor (ash) and particulate from the APC. Scrubber water from the APC is generally recycled. Rotary kiln incinerators are the most versatile and the most proven of all devices for waste soil incineration.

On-site rotary kiln incinerators are available as either mobile or transportable units. Mobile units are small-capacity systems permanently installed on two or three trucks that are typically used at sites where the waste quantity ranges up to 20,000 tons. The incineration of larger volumes can be conducted more effectively using transportable system that occupy 5 to 30 trucks and that require on-site assembly.

- Effectiveness. Based on the general effectiveness of thermal destruction methods for organics, treatment by rotary kiln incineration has the potential to destroy organic contaminants to the maximum extent feasible. Full-scale field demonstrations of rotary kiln incineration have demonstrated a Destruction Removal Efficiency (DRE) of greater than 99.99 percent for soils containing explosive compounds[35,36]. Full-scale incineration of explosive-contaminated soils, using transportable rotary kiln incinerators, has been implemented at two Army installations. Although potentially reducing the volume of contaminated soil, incineration does not result in the destruction of metals and is not an appropriate technology for the treatment of soil contaminated with only metals. It is, however, a feasible technology for the pretreatment of soil contaminated with both organics and metals for the removal of organics prior to subsequent treatment to remove or stabilize the metals.

- Implementability. The implementability of on-site rotary kiln incineration has been demonstrated on the full-scale to treat explosive-contaminated soil at two Army installations. Explosives concentrations in Miscellaneous Sites soils do not appear to be a constraint. Studies conducted by USATHAMA indicate that sediments with explosive concentrations higher than those in Miscellaneous Sites soils can be fed directly to the primary combustion chamber of an incinerator without exceeding acceptable safety limitations[38].

- Cost. The unit cost of mobile and transportable rotary kiln incineration is highly dependent on the total mass of soil. Because of the fixed costs of site preparation, mobilization, and trial burns, the cost per ton increases as the total mass decreases. In a survey conducted by McCoy and Associates, Inc., unit operating costs estimated by two vendors of mobile rotary kiln incinerators ranged from \$250 to \$750 per ton[38]. In the same survey, vendor operating costs for transportable rotary kiln incinerators ranged from \$200 to \$450 per ton. These costs did not include excavation, site preparation, or solids handling. The results of another estimate indicated that total incineration costs for Superfund sites, including excavation, permitting, and ancillary equipment, were in the \$200 to \$650 per ton range [38]. Total project costs for the incineration of explosives-contaminated soil at Cornhusker Army Ammunition Plant were \$260 per ton (40,000 tons total) and \$330 per ton (102,000 tons total) at the Louisiana Army Ammunition Plant.

- Summary. On-site rotary kiln incineration is selected for further detailed evaluation because it is the single technology whose effectiveness and implementability have been demonstrated in similar applications involving organic (including explosives) contaminated soil.

2.4.2.2.9 Ex Situ Glassification. A variety of thermal technologies exists for the treatment of solids containing organic contaminants. These techniques thermally oxidize or pyrolyze combustible pollutants at elevated temperatures to produce the combustion products carbon dioxide and water. Other elemental constituents such as nitrogen, halogens, phosphorus, and sulfur are typically converted to acidic vapors. Thermal treatment for wastes containing significant concentrations of metals is a difficult process to operate and avoid volatizing metals to the environment.

Advantages of thermal glassification of wastes include:

- Metals and inorganics will be fixed (and thus immobile).
- The technology is based on well-understood and developed technology.
- The glass product will be highly leach resistant.

Glass-making furnaces may be heated electrically (Joule heating) or by firing fossil fuels such as gas, oil, or coal. Preparation of the furnace feed, to minimize the amount of glass forming chemicals that would be required to produce a melt with the required viscosity at the operating temperature, would likely require judicious selection among the various clays, and sandy-soils. The glass forming chemicals to be added would probably be sodium alkalies, and we expect that perhaps as much as 25 weight percent of the furnace feed will be glass formers required to achieve satisfactory operation. For fossil fuel fired furnaces, sandy fine clays and sands may require agglomeration in order to reduce the entrainment of particulates into the offgas.

Because glassification must be carried out at high temperatures [typically 1200°C (2200°F)], the glass-making operation can generate fumes that are extremely difficult to remove from the offgases. For this reason, the air pollution control system may require sophisticated equipment such as sonic scrubbers for removal of fumes and small size particulates. Depending upon the relative volatility of chemical species, it might be possible to return the scrubber liquid to the glassification furnace for incorporation of the captured particulates into the glass.

Chlorides and sulfates may create problems in glassification because these are not readily incorporated into the glass and are the source of fumes (e.g., sodium chloride will be a liquid with an appreciable vapor pressure at the operating temperature) that tend to exacerbate corrosion in the offgas handling equipment.

Because of the addition of glass formers and despite the density of the glass products, it is likely that the volume of the glassified product will be somewhat greater than the volume of materials processed.

- Effectiveness. The glassification technology has been shown to be effective with a variety of organic compounds and metals[33]. Glassification has not been demonstrated for use with explosives; however, extrapolation of results of incineration of explosive-contaminated soil at temperatures of 1500 to 1800°F [34] indicate that explosives would most likely be successfully oxidized at glassification temperatures.

- Implementability. Glassification makes use of well-established technology for the melting of glass. Glassification involves high temperature (typically 2200°F) treatment of contaminated solids for the purpose of destroying organic contaminants and immobilizing metals (and most other inorganics) contaminants in a glass residual product form. Organic components of wastes are thermally oxidized. Offgases are vented through a scrubber. Ash containing inorganic components is entrapped in the glass.

- Cost. The capital cost of a glass-making furnace is very high which makes it uneconomical for all but very large volumes of soil. Estimated capital costs of available glass-making furnaces are in the area of $38,000,000. Considering the volume of soils to be treated at the Miscellaneous Sites, it is obvious that the per unit treatment cost is extremely high (approximately $7,600 per cubic yard for capital expenditure alone).

- Summary. Although glassification is a technically feasible option, due to the combination of relatively low volumes of soil to be treated and the high capital equipment cost, this alternative is eliminated from further consideration.

2.4.2.2.10 Off-Site Treatment and/or Disposal. Although the NCP specifies a preference for on-site remedies, there are certain circumstances in which off-site treatment and/or disposal may be preferable: particularly for smaller waste volumes. The potential for some of the Miscellaneous Sites soils to exhibit the toxicity characteristic due to the presence of lead would require that implementation of this option involve extensive analyses and segregation of soils according to their toxicity characteristic. Soil exhibiting the toxicity characteristic would require treatment prior to disposal. Other soils could be disposed of as nonhazardous wastes.

- Effectiveness. Removing the contaminated soil from the Miscellaneous Sites would be effective in achieving the remedial action objectives.

- Implementability. The excavation of contaminated soil followed by transporting the soil to an off-site facility for treatment and/or disposal is one of the oldest and most established forms of soil remediation - particularly for small volumes of soil. It can be an expedient means of achieving the remedial action objectives. Implementability is negatively affected by requirements for manifesting and decontamination associated with transportation of the contaminated material. In addition, implementability may be affected by negative public opinion regarding movement of contaminated soil from the installation to a treatment/disposal facility.

- Cost. Costs for off-site treatment and/or disposal are dependent on the volume of soil involved, specific requirements for treatment, and availability and location of a suitable treatment/disposal facility. Estimated costs for excavation, transportation off site, soil treatment, and residue disposal are $1,000 per cubic yard of soil requiring treatment prior to disposal. Costs for excavation, transportation off site, and disposal of nonhazardous soil are estimated at $80 per cubic yard of soil.

- Summary. Off-site treatment and/or disposal would achieve the remedial action objectives and there is potential that it could be cost effective considering the relatively small volumes of soil involved. Implementation of the option may be negatively impacted by regulatory requirements and public opinion; however, off-

site treatment and/or disposal has been a frequently used remedial alternative. Because of the potential for off-site treatment and/or disposal to be expediently implemented and cost effective, this alternative is retained for further consideration for the contaminated soils at the Miscellaneous Sites.

3.0 Development of Alternatives

The two stages of screening potential technologies and process options for actions addressing soil contamination at the Miscellaneous Sites, as described in Section 2.0, Identification and Screening of Technologies, resulted in the selection of those technologies and process options that had potential applicability based on a determination of effectiveness, implementability, and cost. Those technologies and process options that survived the final screening were assembled and remedial alternatives were developed that consist of one or more of the options. These alternatives will be subjected to a detailed analysis that will be presented in Section 4.0, Detailed Analysis of Alternatives.

The developed alternatives with a summary of the primary actions involved in each of the alternatives are presented in Table 3-1 and are described in more detail below. Table 3-1 will provide a reference to the identification of specific alternatives to be addressed in Section 4.0, Detailed Analysis of Alternatives.

3.1 Alternative 1: No Action

The No Action alternative serves as a common reference point for the analysis of alternatives that result in the remediation of the Miscellaneous Sites. It provides a basis for comparison between the various alternatives. Implementation of the No Action alternative does not imply immediate abandonment of the Miscellaneous Sites. Existing security provisions to limit access to the Miscellaneous Sites would be continued.

3.2 Alternative 2: Institutional Control and Containment

This alternative is composed of two options that reflect the actions of placing institutional controls on the future use of the Miscellaneous Sites and on-site containment of the contaminated soil. Specific options are described below. Although fencing the individual sites may not be required providing that appropriate access restrictions can be maintained, fencing has been included in this evaluation as a conservative approach to applying institutional controls.

3.2.1 Alternative 2A

Specific actions required for the implementation of this alternative include:

- Fence the Miscellaneous Sites.
- Place a layer of clean soil over the contaminated areas.
- Plant vegetation over the layer of clean soil.
- Restrict access to the Miscellaneous Sites.

3.2.2 Alternative 2B

This alternative differs from Alternative 2A in that containment of contaminated soil is achieved by the use of an engineered cap. Specific actions include:

Table 3-1. Summary of Alternatives for the Miscellaneous Sites

Alternative	General Alternative Description	Option	Option Description	Primary Option Actions
1	No Action	None		
2	Institutional Control and Containment	A	Restrict access, soil cover, vegetation	Fence sites, place clean soil over contaminated areas, plant vegetation over clean soil
		B	Restrict access, engineered cap, vegetation	Fence sites, place engineered cap over contaminated areas, plant vegetation over cap
3	On-Site Treatment Solidification/Stabilization (S/S)	A	Pretreat by soil washing, S/S, off-site landfill of S/S residuals	Excavate soil, soil wash to reduce volume, S/S of contaminated fraction, off-site disposal of nonhazardous treated materials
		B	Pretreat by soil washing, S/S on-site disposal of S/S residuals, cover	Excavate soil, soil wash to reduce volume, S/S of contaminated fraction, on-site disposal of nonhazardous S/S residuals in active landfill (Option B[1]) or new landfill (Option B[2])
		C	S/S, off-site landfill of S/S residuals	Excavate soil, S/S of soil, off-site disposal of nonhazardous S/S residuals in off-site landfill
		D	S/S, on-site disposal of S/S residuals	Excavate soil, S/S of soil, on-site disposal of nonhazardous S/S residuals in active landfill (Option D(1)) or new landfill (Option D(2))
4	On-Site Treatment - Incineration and Solidification/Stabilization (S/S)	A	Pretreat by soil washing, incineration, S/S, off-site disposal of S/S residuals	Excavate soil, soil wash to reduce volume, incinerate organic fraction, S/S incinerator residues and metal fraction off-site disposal of nonhazardous S/S residuals in landfill
		B	Pretreat by soil washing, incineration, S/S, on-site disposal of S/S residuals	Excavate soil, soil wash to reduce volume, incinerate organic fraction, S/S incinerator residuals and metal fraction, on-site disposal of nonhazardous residuals in active landfill (Option [1]) or new landfill (Option B(2))
		C	Incineration, S/S, off-site disposal of S/S residuals	Excavate soil, incinerate soil containing organics, S/S incinerator residues and metal-contaminated soil, off-site disposal of non-hazardous S/S residuals in landfill
		D	Incineration, S/S, on-site disposal of S/S residuals	Excavate soil, incinerate soil containing organics, S/S incinerator residues and metal-contaminated soil, on-site disposal of non-hazardous residuals in active landfill (Option D[1]) or new landfill (Option D[2])

Table 3-1. Summary of Alternatives for the Miscellaneous Sites (continued)

Alternative	General Alternative Description	Option	Option Description	Primary Option Actions
5	**Off-Site Treatment of Organic-Only-Contaminated Soil and On-Site Solidification/Stabilization of Metal-Contaminated Soil**	A	Off-site incineration, on-site S/S, off-site disposal of S/S residuals	Excavate soil, transport organic-only contaminated soil off site for treatment by incineration, on-site S/S of metal-contaminated soils, off-site disposal of nonhazardous S/S residuals in landfill
		B	Off-site incineration, on-site S/S of metal-contaminated soil, on-site disposal of S/S residuals	Excavate soil. Transport organic-only contaminated soil off site for treatment by incineration, on-site S/S of metal-contaminated soils, on-site disposal of nonhazardous S/S residuals in active landfill (Option B[1]) or new landfill (Option B[2])
6	**Off-Site Treatment and Disposal**	A	Off-site treatment of hazardous soil, off-site disposal of non-hazardous soil	Excavate soil, segregate hazardous and nonhazardous soils. Transport soils off site for treatment of hazardous soil and landfill disposal of nonhazardous soil

S/S - solidification/stabilization

Source: Arthur D. Little, Inc.

- Fence the Miscellaneous Sites.
- Place an engineered cap consisting of layers of clay and clean soil over the contaminated areas.
- Plant vegetation over the layer of clean soil.
- Restrict access to the Miscellaneous Sites.

3.3 Alternative 3: On-Site Soil Treatment - Solidification/Stabilization

This alternative would provide for the remediation of the contaminated soil using the technology of solidification/stabilization. Four options for this alternative are developed to address pretreatment of the soil to reduce its volume and the disposal of treatment residuals. These options are described below.

3.3.1 Alternative 3A

This alternative makes use of the soil washing technology to reduce the volume of contaminated soil to be treated by solidification/stabilization. Specific actions involved include:

- Excavate contaminated soil.
- Conduct treatability studies of the use of soil washing and solidification/stabilization to determine effectiveness and process parameters.
- Pretreat excavated soil by soil washing to reduce the volume of contaminated material.
- Treat the contaminated fraction resulting from soil washing by solidification/stabilization.
- Confirm, by testing and analyses, that treatment residuals are nonhazardous.
- Dispose of the treatment residuals in an off-site landfill.

3.3.2 Alternative 3B

This alternative differs from Alternative 3A in that on-site disposal of treatment residuals is considered instead of off-site disposal. Specific actions involved include:

- Excavate contaminated soil.
- Conduct treatability studies of the use of soil washing and solidification/stabilization to determine effectiveness and process parameters.
- Pretreat excavated soil by soil washing to reduce the volume of contaminated material.
- Treat the contaminated fraction resulting from soil washing by solidification/stabilization.
- Confirm, by testing and analyses, that treatment residuals are nonhazardous.
- Dispose of the treatment residuals in the on-site active landfill (Option B[1]) or in a new, engineered, on-site landfill (Option B[2]).

3.3.3 Alternative 3C

In this alternative, the entire volume of contaminated soil is treated by solidification/stabilization - there is no pretreatment to reduce contaminated soil volume. Specific actions involved include:

- Excavate contaminated soil.
- Conduct treatability studies of solidification/stabilization to determine effectiveness and process parameters.
- Treat contaminated soil by solidification/stabilization.
- Confirm, by testing and analyses, that treatment residuals are nonhazardous.
- Dispose of the treatment residuals in an off-site landfill.

3.3.4 Alternative 3D

This alternative differs from Alternative 3C in that on-site disposal of treatment residuals is considered instead of off-site disposal. Specific actions involved include:

- Excavate contaminated soil.
- Conduct treatability studies of solidification/stabilization to determine effectiveness and process parameters.
- Treat contaminated soil by solidification/stabilization.
- Confirm, by testing and analyses, that treatment residuals are nonhazardous.
- Dispose of the treatment residuals in the on-site active landfill (Option D[1]) or in a new, engineered, on-site landfill (Option D[2]).

3.4 Alternative 4: On-Site Soil Treatment - Incineration and Solidification/Stabilization

This alternative would provide for the remediation of the contaminated soil by incinerating the organic-contaminated soil and treating the incinerator residues and metal-contaminated soil by solidification/stabilization. Four options for this alternative are developed to address pretreatment of the soil to reduce its volume and the disposal of treatment residuals. These options are described below.

3.4.1 Alternative 4A

This alternative makes use of the soil washing technology to reduce the volume of contaminated soil to be treated by incineration and solidification/stabilization. Specific actions involved include:

- Excavate contaminated soil.
- Conduct treatability studies of the use of soil washing and solidification/stabilization to determine effectiveness and process parameters.
- Pretreat excavated soil by soil washing to reduce the volume of contaminated material.
- Mobilize mobile incinerator on-site.

- Conduct trial burns.
- Incinerate concentrated organic-contaminated soil.
- Subject concentrated metal-contaminated soil and incinerator residues to solidification/stabilization.
- Confirm, by testing and analyses, that treatment residuals are nonhazardous.
- Dispose of the treatment residuals in an off-site landfill.

3.4.2 Alternative 4B

This alternative differs from Alternative 4A in that on-site disposal of treatment residuals is considered instead of off-site disposal. Specific actions involved include:

- Excavate contaminated soil.
- Conduct treatability studies of the use of soil washing and solidification/stabilization to determine effectiveness and process parameters.
- Pretreat excavated soil by soil washing to reduce the volume of contaminated material.
- Mobilize mobile incinerator on-site.
- Conduct trial burns.
- Incinerate concentrated organic-contaminated soil.
- Subject concentrated metal-contaminated soil and incinerator residues to solidification/stabilization.
- Confirm, by testing and analyses, that treatment residuals are nonhazardous.
- Dispose of the treatment residuals in the on-site active landfill (Option B[1]) or in a new, engineered, on-site landfill (Option B[2]).

3.4.3 Alternative 4C

In this alternative, the entire volume of contaminated soil is treated by incineration and/or solidification/stabilization-- there is no pretreatment to reduce contaminated soil volume. Specific actions involved include:

- Excavate contaminated soil.
- Conduct treatability studies of solidification/stabilization to determine effectiveness and process parameters.
- Mobilize mobile incinerator on-site.
- Conduct trial burns.
- Incinerate concentrated organic-contaminated soil.
- Subject concentrated metal-contaminated soil and incinerator residues to solidification/stabilization.
- Confirm, by testing and analyses, that treatment residuals are nonhazardous.
- Dispose of the treatment residuals in an off-site landfill.

3.4.4 Alternative 4D

This alternative differs from Alternative 4C in that on-site disposal of treatment residuals is considered instead of off-site disposal. Specific actions involved include:

- Excavate contaminated soil.
- Conduct treatability studies of solidification/stabilization to determine effectiveness and process parameters.
- Mobilize transportable incinerator on-site.
- Conduct trial burns.
- Incinerate concentrated organic-contaminated soil.
- Subject concentrated metal-contaminated soil and incinerator residues to solidification/stabilization.
- Confirm, by testing and analyses, that treatment residuals are nonhazardous.
- Dispose of the treatment residuals in the on-site active landfill (Option D[1]) or in a new, engineered, on-site landfill (Option D[2]).

3.5 Alternative 5: Off-Site and On-Site Treatment and Disposal

This alternative would provide for the removal of organic-only-contaminated soil from UMDA for off-site treatment and disposal. Metal-contaminated soils would be treated by solidification/stabilization on-site.

3.5.1 Alternative 5A

In this alternative, treatment residuals from the on-site solidification/stabilization of metal-contaminated soil would be disposed of off site in a landfill as nonhazardous materials. The following actions would be involved in the implementation of this alternative:

- Excavate contaminated soil.
- Transport organic-only-contaminated soil off-site for treatment.
- Conduct treatability studies of solidification/stabilization to determine effectiveness and process parameters.
- Treat metal-contaminated soil on site by solidification/stabilization.
- Confirm, by testing and analyses, that treatment residuals are nonhazardous.
- Dispose of the treatment residuals in an off-site landfill.

3.5.2 Alternative 5B

This alternative differs from the previous alternative in that treatment residuals generated by the on-site solidification/stabilization of metal-contaminated soils would be disposed of on site. The following actions would be involved in the implementation of this Alternative:

- Excavate contaminated soil
- Transport organic-only-contaminated soil off site for treatment
- Conduct treatability studies of solidification/stabilization to determine effectiveness and process parameters
- Treat metal-contaminated soil on site by solidification/stabilization

- Confirm, by testing and analyses, that treatment residuals are nonhazardous
- Dispose of the treatment residuals in the on-site active landfill (Option B[1]) or in a new, engineered, on-site landfill (Option B[2]).

3.6 Alternative 6: Off-Site Treatment and Disposal

This alternative would provide for the removal of contaminated soil from UMDA for off-site treatment and disposal. The following actions would be involved in the implementation of this alternative:

- Excavate contaminated soil
- Determine hazardous characteristics of excavated contaminated soil
- Segregate RCRA hazardous and nonhazardous contaminated soil
- Prepare manifests for the transport of the RCRA hazardous contaminated soil
- Transport RCRA hazardous and nonhazardous soil to a RCRA-permitted facility for the treatment of hazardous soil and the disposal of nonhazardous soil in a landfill

4.0 Detailed Analysis of Alternatives

The alternatives developed in Section 2.0, Identification and Screening of Technologies and Section 3.0, Development of Alternatives, are summarized in Table 3-1. For the Miscellaneous Sites, six basic alternatives are to be considered. Some of these alternatives include a number of options to provide adequate input to remedial alternative selection.

The purpose of this section of the FS is to present information relevant to selecting an appropriate remedy for the Miscellaneous Sites. The analyses were performed in accordance with the requirements of the NCP, CERCLA, SARA, the Interim Guidance on Superfund Selection of Remedy, and the Oregon Hazardous Substance Remedial Action Rules. The analyses are also based on the institutional and technical criteria presented in Section 2.0, Identification and Screening of Technologies.

4.1 CERCLA Evaluation Criteria

The detailed analysis of alternatives consists of the evaluation and presentation of the relevant information needed to allow decision makers to select a site remedy. In developing this analysis there are five specific statutory requirements for remedial actions that must be addressed, including:

- Protection of human health and the environment
- Attainment of ARARs
- Cost-effectiveness
- Use of permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable
- Preference for treatment that reduces toxicity, mobility, and/or volume as the principal element

In addition, CERCLA places an emphasis on evaluating long-term effectiveness and related considerations for each of the alternatives, including:

- The long-term uncertainties associated with land disposal
- The goals, objectives, and requirements of the Solid Waste Disposal Act
- The persistence, toxicity, and mobility of hazardous substances and their constituents, and their propensity to bioaccumulate
- Short- and long-term potential for adverse health effects from human exposure
- Long-term maintenance costs
- The potential for future remedial action costs if the alternative remedial action in question were to fail
- The potential threat to human health and the environment associated with excavation, transportation, and redisposal, or containment.

Each of these requirements and considerations were then combined in the NCP, and nine evaluation criteria were developed to address the intent of the requirements and

considerations and other technical and policy considerations that have proven to be important for selecting remedial alternatives. These nine evaluation criteria have served as the basis for conducting the detailed analysis of the six remedial alternatives for the Miscellaneous Sites. In order to ensure that the appropriate weight was applied to each of the criteria, the NCP divides the nine criteria into three groups (as shown in Figure 4-1): 1) Threshold Criteria; 2) Primary Balancing Criteria; and 3) Modifying Criteria.

4.1.1 Threshold Criteria

Two of the criteria relate directly to statutory requirements that must ultimately be satisfied in the ROD. They are categorized as threshold criteria because any alternative selected to remediate the Miscellaneous Sites must meet them. They can be described as follows:

- Overall Protection of Human Health and the Environment - Describes how each alternative, as a whole, achieves and maintains protection of human health and the environment. This assessment draws on the assessments conducted under other evaluation criteria, especially long-term and short-term effectiveness and compliance with ARARs. It focuses on whether a specific alternative achieves adequate protection and describes how site risks are eliminated, reduced or controlled through treatment, engineering, or institutional controls.

- Compliance with ARARs - Describes how each alternative complies with ARARs, or if a waiver is required and how it is justified. The assessment also addresses other information from advisories, criteria, and guidance that the agencies agree is "to be considered." The detailed analysis summarizes which federal and state of Oregon requirements are applicable or relevant and appropriate for the specific alternative and how the alternative meets these requirements.

4.1.2 Primary Balancing Criteria

Five of the criteria are grouped together because they represent the primary factors upon which the analysis is based, taking into account technical, cost, institutional, and risk concerns.

- Long-Term Effectiveness and Permanence - Evaluates the effectiveness of each alternative in maintaining protection of human health and the environment after response objectives have been met. This assessment considers the magnitude of the residual risk (in this case, risk from contaminated soil that is not treated and risk from treatment residuals, if any), measured by numerical standards where possible. It also considers the adequacy and reliability of controls.

- Reduction of Toxicity, Mobility, and Volume through Treatment - Evaluates the anticipated performance of the specific treatment technologies each alternative might employ. Where possible, numerical comparisons before and after remediation are

Figure 4-1: Criteria for Detailed Analysis of Alternatives

Threshold Criteria

OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

- How Each Alternative Provides Human Health and Environmental Protection

COMPLIANCE WITH ARARs

- Compliance with Chemical-Specific ARARs
- Compliance with Action-Specific ARARs
- Compliance with Location-Specific ARARS
- Compliance with Other Criteria, Advisories, and Guidances

Primary Balancing Criteria

LONG-TERM EFFECTIVENESS AND PERMANENCE

- Magnitude of Residual Risk
- Adequacy and Reliability of Controls

REDUCTION OF TOXICITY, MOBILITY, AND VOLUME THROUGH TREATMENT

- Treatment Process Used and Materials Treated
- Amount of Hazardous Materials Destroyed or Treated
- Degree of Expected Reductions in Toxicity, Mobility, and Volume
- Degree to Which Treatment is Irreversible
- Type and Quantity of Residuals Remaining After Treatment

SHORT-TERM EFFECTIVENESS

- Protection of Community During Remedial Actions
- Protection of Workers During Remedial Actions
- Environmental Impacts
- Time Until Needed Remedial Action Objectives are Achieved

IMPLEMENTABILITY

- Ability to Construct and Operate the Technology
- Reliability of the Technology
- Ease of Undertaking Additional Remedial Actions, if Necessary
- Ability to Monitor Effectiveness of Remedy
- Ability to Obtain Approvals From Other Agencies
- Coordination With Other Agencies
- Availability of Necessary Equipment and Specialists
- Availability of Prospective Technologies

COST

- Capital Costs
- Operating and Maintenance Costs
- Present Worth Cost

Modifying Criteria

STATE ACCEPTANCE

COMMUNITY ACCEPTANCE

ce: EPA RI/FS Guidance Manual

presented. This assessment also considers the degree to which treatment is irreversible, the type and quantity of residuals that will remain following treatment, and the degree to which the treatment reduces the inherent hazards posed by the site.

- Short-Term Effectiveness - Examines the effectiveness of each alternative in protecting public health, worker health, and the environment during the construction and implementation of a remedy until response objectives have been met. The time until protection is achieved is also considered here.

- Implementability - Evaluates the technical and administrative feasibility of each alternative and the availability of required goods and services. Technical feasibility includes the ability to construct the system used, the ability to operate and maintain the equipment, and the ability to monitor and review the effectiveness of operations. Administrative feasibility refers to the ability to obtain normal legal approvals (e.g., site access), public relations and community response, and coordination with government regulatory agencies.

- Cost - Evaluates the capital and operation and maintenance (O&M) costs of each alternative. Capital cost refers to the expenditures required to develop and construct the facilities necessary to implement the alternative. O&M cost refers to the expenditures of time and materials throughout the course of the remediation, including costs to lease equipment. The costs presented in the detailed analysis are intended to provide an accuracy of +50 percent to -30 percent.

The level of detail required to analyze each alternative against these evaluation criteria depends on the type and complexity of the site, the type of technologies and alternatives being considered, and other project-specific considerations. This FS addresses soils at the Miscellaneous Sites contaminated by metals, explosives, and/or pesticides. The detail presented in the following analysis has been focused accordingly.

4.1.3 Modifying Criteria

In accordance with RI/FS guidance, the final two criteria involving state and community acceptance will be evaluated following the receipt of state agency and public comments on the FS and the Proposed Plan. The criteria are as follows:

- State (Support Agency) Acceptance - Reflects the state of Oregon's apparent preferences among or concerns regarding the alternatives. State input and acceptance is obtained during preparation of the Final FS and Proposed Plan through the state's role as an equal partner to the Army and EPA in the Federal Facility Agreement.

- Community Acceptance - Reflects the local communities' apparent preferences among or concerns about alternatives.

4.2 Analysis of Alternatives

4.2.1 Common Elements

The processes and procedures that are common to more than one of the remedial alternatives are presented here to minimize redundancy. Reference will be made to these common elements as appropriate in subsequent analyses of alternatives.

4.2.1.1 Institutional Controls. The implementation of institutional controls would involve taking legal and physical measures to restrict access and use of the Miscellaneous Sites. Legal restrictions would have two purposes:

- Restricting access to the Miscellaneous Sites to prevent direct human exposure to contaminants through legal limitations on who may conduct activities at the Miscellaneous Sites

- Restricting future land use at the Miscellaneous Sites to prevent or limit residential or light industrial development

If imposed, these legal restrictions would be retained permanently at the Miscellaneous Sites.

Physical measures used as institutional controls include fencing to limit access to individual Miscellaneous Sites.

The maintenance of institutional controls at the Miscellaneous Sites would require continued monitoring to ensure the absence or control of contamination. In addition, the employment of institutional controls would require the conduct of five-year reviews intended to evaluate whether the alternative remains protective of public health and the environment.

Cost elements associated with the implementation of institutional controls include the costs of fencing, monitoring, and five-year reviews. Specific costs associated with the employment of institutional controls will be addressed in the discussion of the appropriate alternative.

4.2.1.2 Excavation of Soil. The implementation of Alternatives 3, 4, 5, and 6 involves the excavation of contaminated soils. Excavation of soil would be conducted as follows:

- Excavation and hauling would be done using conventional equipment and technology (e.g., backhoes, front-end loaders, dump trucks, scrapers).

- Excavation to a depth of 20 feet would require that sides of the excavation be sloped as appropriate for sideslope stability and shoring would not be required.
- The soil would be loaded on dump trucks and hauled to a predetermined location near the treatment area.

Costs for excavation and loading associated with an unshored, uncontaminated excavation in similar circumstances have been estimated at approximately $7 per cubic yard of soil.

Excavated sites will be restored by backfill with clean soil and revegetation with native plants.

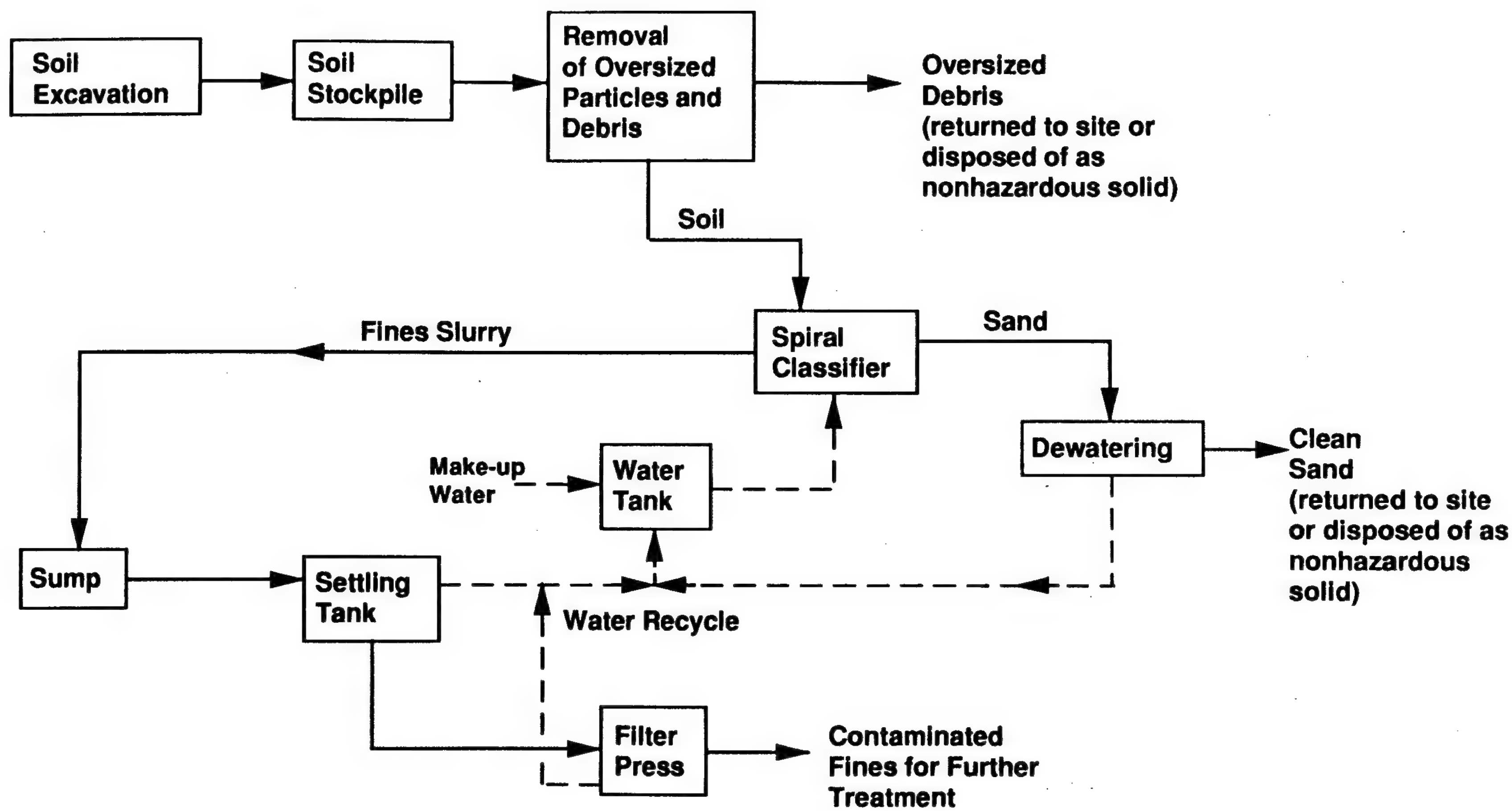
4.2.1.3 Soil Washing to Reduce Contaminated Soil Volume. The physical separation of contaminated fine soil particles (e.g., silt and clay) from larger soil particles (e.g., sand) by washing with water, agitation and particle classification may be an effective method to reduce the volume of contaminated soil that requires subsequent treatment or disposal.

When used with contaminated soils, the soil washing process makes use of the fact that finer particles have a much larger surface area per unit volume than do larger soil particles. When the contaminants are uniformly distributed over the surface of the soil particles, a greater proportion of the contamination is concentrated on the fine soil particles with their large surface area per unit volume, leaving the larger particles relatively free of contamination. Ideally, separation of the contaminated soil into fines that are highly contaminated and a relatively uncontaminated large particle fraction allows for a significant reduction in soil volume requiring further treatment or disposal. Soil (i.e., sand) that meets the cleanup levels can be returned to the site or otherwise disposed of as a nonhazardous solid waste.

Process Description. A representative soil washing process is presented in Figure 4-2. As shown, the excavated and stockpiled contaminated soil is screened to remove oversized (greater than 0.25 inch) particles and debris. The finer soil is conveyed to a spiral classifier where water is introduced and the separation of the fines from the sand occurs. The sand is dewatered and returned to the site or handled as a nonhazardous material. The resulting fines slurry is pumped to a settling tank where the fines settle as a sludge, leaving clear water to be recycled. A flocculating polymer may be added at this step to enhance settling, if necessary. After settling, the fines are pumped to a filter press for further dewatering. At this point, the concentrated and dewatered contaminated fines can be subjected to further treatment for toxicity reduction and/or solidification/stabilization.

A review of the technology was performed for the EPA in support of a remedial alternative evaluation at the Deactivation Furnace site at UMDA. In this review, it was determined that, based on the particle size and contaminant distribution in these soils, the

Figure 4-2: Schematic of Soil Washing Process



Source: Reference 28 and Arthur D. Little, Inc.

contaminated media could be concentrated to a volume that is 20 percent of the original soil volume [31]. Although similar particle size and contaminant distribution characterizations were not performed for soils at the Miscellaneous Sites, it is assumed for the purpose of this evaluation that these soils are adequately similar to permit the same volume reduction assumption.

The low solubility of the contaminants of concern in water will most likely allow for the washwater to be recycled without treatment. It is assumed that once the soil washing process is complete, the water will be treated by lime precipitation in the existing settling tank to remove any soluble metals. If organic compounds are present in the water, further treatment by activated carbon adsorption may be necessary prior to discharge of the water. Based on the solubility of the contaminants in water, it may not be necessary to treat the water prior to discharge once the soil washing has been completed[28].

Soil washing is considered an innovative technology. As such, a treatability study would be required to confirm the effectiveness of the process and identify operating parameters and develop cost estimates for full-scale implementation.

The primary cost elements of soil washing include capital costs associated with the purchase and installation of the various pieces of equipment used, and operating costs such as labor, maintenance, and utilities (electricity and water).

Assumptions regarding the implementation of soil washing include[28]:

- A nominal feed soil rate of approximately 6 tons per hour
- An operating schedule of 260 days per year, 8 hours per day, and 70 percent operational time on line

4.2.1.4 Solidification/Stabilization. Solidification/stabilization has been proven most useful for the treatment of inorganic contaminants (including heavy metals). Its utility for the treatment of many organic-containing wastes may be limited due to the potential for detrimental chemical interactions, the volatility of the organic compounds, and limited success in reducing organic mobility. Because of the relatively low concentrations of primarily nonvolatile organic contaminants in Miscellaneous Sites soils, the likelihood for detrimental chemical interactions and volatility are lessened. However, the ability of the process to reduce the mobility of the organic contaminants is unknown and would require confirmation through treatability studies.

Process Description. Stabilization and solidification waste treatment processes involve the mixing of specialized additives or reagents with waste materials to reduce (physically or chemically) the solubility or mobility of contaminants in the matrix. The term "stabilization" is used to describe techniques that chemically modify the contaminant to form a less soluble, mobile, or toxic form without necessarily changing the physical characteristics of the waste. Solidification refers to a technique for changing the physical

form of the waste to produce a solid structure in which the contaminant is mechanically trapped. Many stabilization and solidification processes overlap, and the common terminology to describe either or both processes is solidification/stabilization.

The types of processes and reagents used in solidification/stabilization processes will be selected based on the characteristics (chemical and physical) of the waste to be treated and on the desired characteristics (chemical and structural) of the treated product. Two common processes are:

- Lime/Fly Ash Pozzolan Reactions - involving a reaction between noncrystalline silica in fly ash and lime to produce a low-strength solid in which contaminants are physically trapped
- Pozzolan/Cement Reactions - which employ a pozzolan such as fly ash and cement to produce a relatively high-strength waste/concrete matrix in which contaminants are trapped

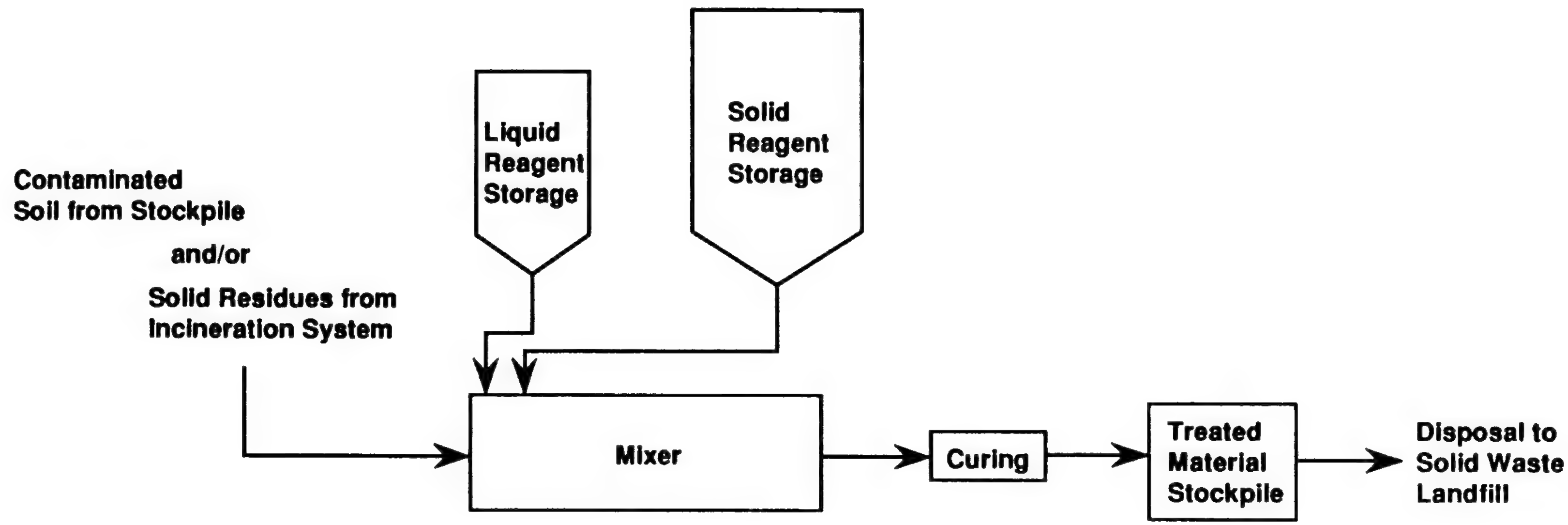
For the purposes of this FS, it will be assumed that the soil and ash to be treated will be subjected to a pozzolan/cement-based process to provide a treated product with maximum physical and chemical stability.

There are a number of configurations of the solidification/stabilization process including: in-drum mixing, in situ mixing, plant mixing, and area mixing[39]. Of these, plant mixing is the most practical for treating soils at the Miscellaneous Sites because it provides for greater throughput, increased control of contaminated materials, increased assurance of treatment effectiveness, and can be performed with transportable equipment. A schematic of the plant mixing process is provided in Figure 4-3.

Transportable solidification/stabilization processes will typically come complete with chemical storage units, chemical feed equipment, mixing equipment, and waste and product handling equipment. Primary concerns with the application of solidification/stabilization include:

- The potential chemical incompatibility between the material being treated and the solidification/stabilization reagents. For example, salts have been shown to cause swelling and cracking in solidified matrices[40].
- The long-term ability of the stabilized/solidified matrix to retain the contaminants. Since solidification/stabilization process normally do not destroy the contaminant but, rather, place it in a nonleachable form, the long-term integrity of the product must be assured.

Figure 4-3: Schematic of Stabilization/Solidification Process



Source: Arthur D. Little, Inc.

These concerns can best be addressed through the conduct of treatability tests. The treatability tests will also allow for the development of proper design and operation criteria.

Implementation of solidification/stabilization would require sufficient land area around the operation to maintain a buffer zone, access roads capable of supporting heavy equipment (in this case, 80,000 lb trailers), and direct and unencumbered accessibility to the waste feed material.

The actual equipment set-up for solidification/stabilization requires area for reagent storage tanks, mixer (or pugmill), and loading equipment. Approximately 0.25 acres will be required for the equipment alone. Additional area is required for loading and unloading soil and treated material, untreated and treated material stockpiles, and truck access.

As stated above, there are a number of options available for management of the treated product. For the purposes of this analysis, it is assumed that the treated product will be discharged to a dump truck or transportable container for transport to final disposal area.

Utility requirements for solidification/stabilization will include:

- A continuous water supply at 60 psi to be used in the treatment reaction. For the purposes of analysis, it is assumed that this water will be available from installation sources. However, if supplies at the treatment site are insufficient, an alternate supply (from on or off the installation) will be required.

- Electrical service of 480V, 3-phase for major equipment operation. In addition, the operation of ancillary operation and support systems will require 15 amp, 120-V, 1-phase service. For the purposes of this analysis, it is assumed that these electrical requirements can be met on the installation.

Approximately 12 to 15 personnel are required to operate the system in a single 10 to 12 hour shift, 6 days per week[41]. These personnel include operators, supervisor, shift foreman, and maintenance personnel. Individual shifts are long to ensure that once the chemical reagents are mixed, they continue to flow without hardening. Typically, maintenance is performed on the seventh day when the system is shut down.

The following testing phases are performed to develop operational parameters and assure quality control of the treated product:

- Waste characterization includes a determination of physical properties of the contaminated soil to include: bulk density, grain size distribution, Atterberg limits (liquid and plastic), cone index, unconfined compressive strength, and percent

moisture. In addition, analyses are performed to identify chemical characteristics that may affect the solidification/stabilization process including acids, solvents, halides, sulfates, pH, metals, solid organic contaminants, and oil and grease.

- Treatability tests will be required to select the appropriate reagent systems and optimize process parameters.

- To assess the quality of the final product, a series of tests are typically performed to determine product characteristics such as leachability, free liquid content, strength, permeability, and durability.

Complete mobilization will typically require approximately six weeks from the completion of treatability testing.

Once operational, the time required to complete the solidification/stabilization of the contaminated media will depend on the total mass to be treated, the throughput, and the operating efficiency. The former factor is alternative-dependent and will be addressed in the discussion of the specific alternatives below. The latter two factors are alternative-independent and assumptions specific to these factors are:

- Operating schedule of 12 hours, 6 days per week with an operational time on line of 70 percent.
- Throughput of process is nominally 350 tons/day (including material to be treated and reagents)[41].

4.2.1.5 On-Site Landfill Disposal of Nonhazardous Soil and/or Treatment Residues. As part of the remediation of soil at the Miscellaneous Sites, soil may be excavated that, although contaminated to the degree that it does not meet remedial action goals, is not a hazardous waste. In addition, residuals resulting from the excavation and treatment of contaminated soil (including rocks and debris separated from the soil prior to treatment, solid treatment byproducts, and the final solid treatment product) may be nonhazardous. A potential disposal option considered for these nonhazardous solids is disposition in the active on-site landfill or in a new, engineered landfill that would be constructed on site.

The existing active landfill shown in Figure 4-4, is located in the eastern portion of UMDA between munition storage blocks D and E. Under an agreement entered into by the Army, this landfill will cease receipt of municipal waste on October 9, 1993, but may receive treated soil from the Deactivation Furnace Area (or soils meeting similar standards) until 1998[42]. The Army is currently in the process of preparing a closure plan for the landfill in accordance with its permit and ODEQ solid waste regulations and guidance. As part of landfill closure requirements, the following actions will be performed:

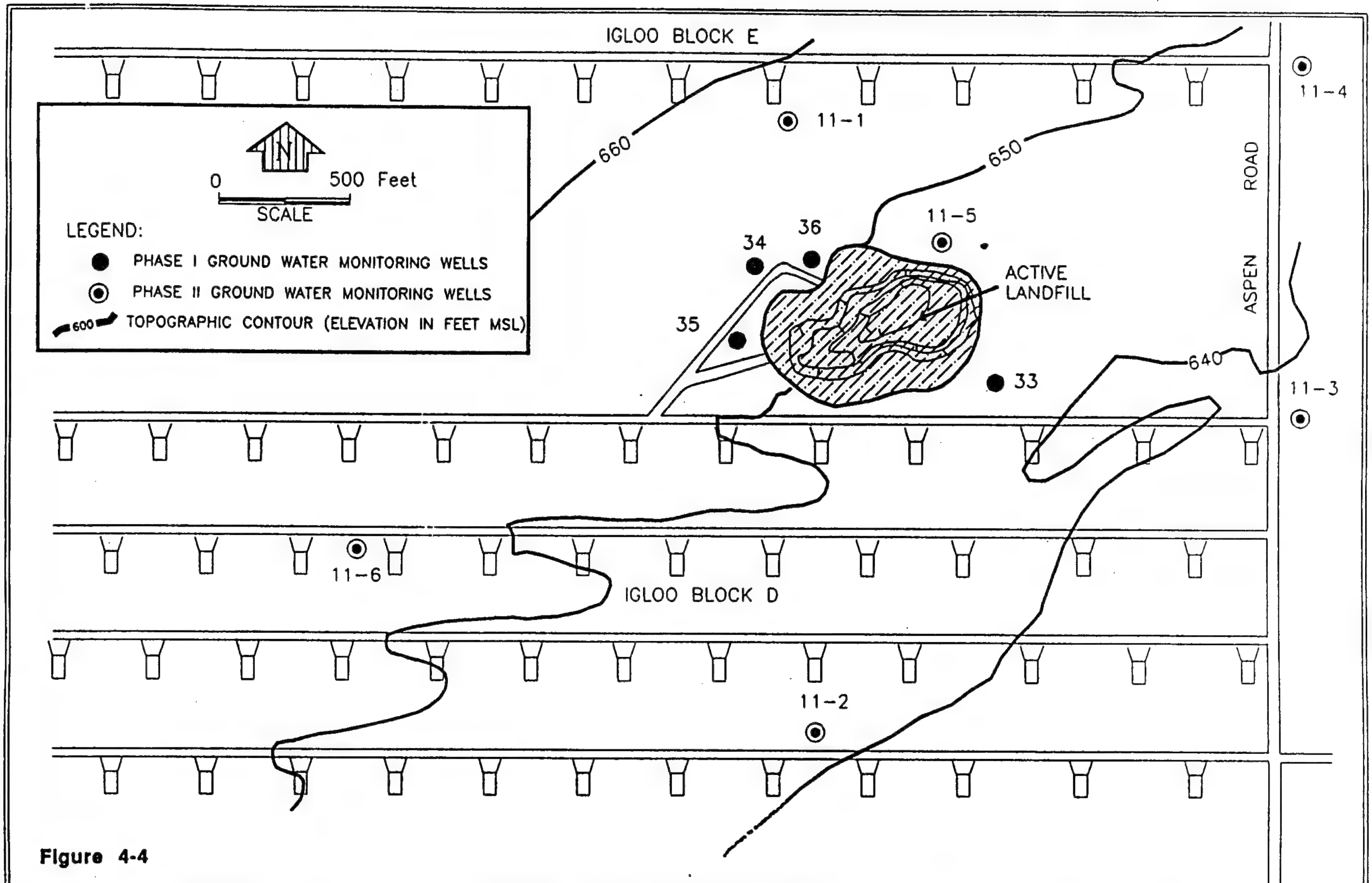


Figure 4-4

PREPARED FOR: UMATILLA		Modified From: Final Remedial Investigation Report for the Umatilla Depot Activity, Hermiston, OR, August, 1992	TITLE: ACTIVE LANDFILL
DATE: SEPT.1992	SCALE: AS SHOWN	DWG. NO. 67062-003	

- The landfill will be capped with a low permeability cap consisting of 18 inches of compacted soil with a permeability no greater than $1x10^{-5}$ cm/second.

- Ground water monitoring will be performed for a period of five years after closure to ensure that the landfill does not constitute a source of contamination.

If it is determined that disposal of these nonhazardous solids in the active landfill is not desired, a new engineered landfill might be designed and constructed on site to receive them. This landfill would be designed and constructed to meet ODEQ solid waste regulations and be located at an appropriate (currently undetermined) location within UMDA. After all nonhazardous solids resulting from the remedial actions at UMDA are deposited in the landfill, it would be closed in accordance with requirements of its permit and ODEQ solid waste regulations and guidance. It is assumed that closure of this landfill will include a cap of compacted soil similar to that proposed for the active landfill as well as ground water monitoring for a period of five years after closure.

Regardless of the option pursued (existing landfill or new landfill), all solid material considered for disposal would require sampling and analysis to confirm that it is nonhazardous.

Costs for transporting the nonhazardous solids from the Miscellaneous Sites to either the active landfill or a new landfill are estimated at approximately $4 per cubic yard of nonhazardous solids to be disposed of. Costs associated with the design and construction of a new landfill will add approximately $56 per cubic yard to the cost of transporting the nonhazardous solids. The cost of closure of the active landfill (a separate Operational Unit) is part of the overall closure plan for that landfill and is not included here. The cost of closure of a new landfill is estimated at approximate $24 per cubic yard of material disposed.

4.2.1.6 Preparation of Remedial Design and Planning Documentation. A number of Remedial Design/Remedial Action planning documents may be required for implementation of a given alternative. These plans may include: Work Plan; Materials Handling Plan; Chemical Data Acquisition Plan; Trial Burn Plan; Erosion and Sedimentation Control Plan; Security Plan; Safety Plan; Traffic Control Plan; and Environmental Protection Plan. The extent and detail to which planning documentation will be required will depend on the specific processes to be employed in the remedial action and the complexity of the on-site remedial action activities. Based on previous remedial activities conducted by the Army, these costs are estimated at 10 percent of the total capital and O&M costs.

4.2.1.7 Additional Cost for Sampling and Analysis. Additional sampling and analysis may be required for site characterization or confirmation during and/or after remediation. Some of these costs will be incurred by the Army regardless of the

alternative selected (with the exception of No Action). These costs are included in the contingency allowances as part of the indirect costs.

4.2.2 Alternative 1: No Action

4.2.2.1 Description of Alternative. According to the NCP, remedy selection must include an analysis of the level of treatment with respect to the expenditures of time and materials required to achieve that level. The No Action alternative serves as a common reference point for this analysis and allows for comparisons between the various alternatives.

No Action does not imply immediate abandonment of the Miscellaneous Sites. Existing security provisions to limit access to the Miscellaneous Sites would be continued.

Natural recovery of the contaminated soil is unlikely at the Miscellaneous Sites due to the characteristics of the dominant contaminants. Due to the low organic content of the Miscellaneous Sites soils as well as the relative resistance of the contaminants to biodegradation, degradation of the contaminants is unlikely. The primary mechanism that may serve to reduce contaminant concentrations is their dispersion (and resulting dilution) by wind. This mechanism is applicable to surface soils only.

The primary route of migration of contaminants in soil at the Miscellaneous Sites is through windblown dust. A course of No Action would do nothing to limit the potential for contaminant migration.

4.2.2.2 NCP Criteria Analysis. The degree to which the No Action alternative satisfies the seven threshold and primary balancing criteria of the NCP is discussed below.

Overall Protection of Human Health and the Environment. This alternative does nothing to enhance protection of adjacent communities, the environment, or future land users. The risks posed by the soil would remain at the current level.

The No Action alternative would present only a minimal risk of exposure to UMDA personnel during routine site activities. The sites are removed from areas of active use, so direct contact with soils would not be expected. However, exposure via the air pathway would be of concern due to the potential for windblown dust at the Miscellaneous Sites. This alternative would not require any further construction or operation activities.

Compliance with ARARs. This alternative would not comply with either state or federal ARARs regarding soil remediation. The excess cancer risk values for potential future exposure at some sites would exceed the acceptable range of 1×10^{-4} to 1×10^{-6} as stated in the NCP (40 CFR 300.430[e][2][i][A][2]). Likewise, the state of Oregon

requires a cleanup to background or, when background is not feasible, to that lowest level that is protective of human health and the environment while cost effective. The No Action alternative does not demonstrate a remedial effort that results in protection of human health or the environment.

Long-Term Effectiveness. This alternative provides no long-term protection of human health and the environment, and the potential for direct exposure to future site users remains.

Reduction in Toxicity, Mobility, and Volume. The No Action alternative achieves little, if any, reduction in the toxicity, mobility, or volume of the contaminants present.

The primary route of migration of contaminants in soil at the Miscellaneous Sites is through windblown dust. A course of No Action would do nothing to limit the potential for contaminant mobility or migration.

Short-Term Effectiveness. Since no remedial activities are conducted, there would be no short-term impacts to workers, the public, or the environment.

Implementability. There are no practical impediments to implementation of this alternative. However, there are administrative considerations that may impact its overall implementability. Among these considerations are regulatory preference for cleanup and the potential for future use restrictions to be imposed as a result of the continued existence of contamination at the Miscellaneous Sites.

Cost. The immediate costs for implementing the No Action alternative would be minimal. However, because the site could pose unacceptable risks to future industrial or residential users, the Army might be required to retain ownership of the Miscellaneous Sites and provide long-term monitoring and management. These costs, while potentially substantial, have not been estimated in this FS because of their indefinite nature.

4.2.3 Alternative 2: Institutional Control and Containment

4.2.3.1 Description of Alternative. This alternative involves the imposition of institutional controls on the Miscellaneous Sites to limit access to (and future use of) the sites. The issues and implications of institutional controls are described in Section 4.2.1.1, Institutional Controls. In additional to Institutional Controls, this alternative involves the containment of contaminated soil at the Miscellaneous Sites by the use of a soil cover with vegetation or a clay/soil cap with vegetation.

The primary purposes of containment of contaminated soil at the Miscellaneous Sites by the use of a soil cover or an engineered (i.e., clay/soil) cap are to minimize direct contact with contaminated soil and reduce the mobility of the contaminants by preventing their

dispersion as windborne dust. A secondary benefit to a soil cover or cap would be the limitation of infiltration from precipitation.

The soil cover under consideration consists of an 18-inch layer of clean soil obtained from uncontaminated areas at UMDA. The clay/soil cap consists of a 24-inch layer of clay covered by 18 inches of soil and gravel.

Activities involved in placing either the soil cover or clay/soil cap include clearing, grubbing, and grading. Once the soil or clay has been placed, it is compacted to the maximum extent possible and vegetation is placed over the cover or cap.

4.2.3.2 NCP Criteria Analysis. The degree to which this alternative satisfies the seven threshold and primary balancing criteria of the NCP is discussed below.

Overall Protection of Human Health and the Environment. The containment of contaminated soils by the placement of a soil cover or clay cap would minimize the exposure of personnel to the contaminants as well as prevent the spread of contaminants as windborne dust. Because of the limited activity imposed by the institutional controls, it would be expected that the lifetime of a soil cover or clay cap would be increased with minimal long-term maintenance or monitoring required.

Compliance with ARARs. The combination of institutional controls would meet the proposed standards considered as a TBC ARAR and described in Section 2.2, Applicable or Relevant and Appropriate Requirements.

The use of containment techniques would not comply with chemical-specific ARARs in that the contaminants would remain in the soil. Since little or no natural degradation is expected to occur with time, the levels of contamination would essentially remain unchanged.

The activities involved in the implementation of Alternative 2 would not be expected to affect protected species present at the UMDA facility, nor affect any off-site designated wetlands.

All actions associated with this alternative can be adequately controlled so that action-specific ARARs can be met. Dust emission sources will be monitored during the handling of the soils and clays to be used for covers or caps. Since the contaminated soil is not excavated and removed, RCRA/LDR requirement do not apply.

Long-Term Effectiveness and Permanence. Under normal circumstances, soil covers or caps are not considered to be either long-term or permanent solutions to contamination. However, through the imposition of institutional controls (i.e., fencing or future use restrictions) to limit future activities at the site, it is expected that the long-

term effectiveness and permanence of these methods of containment will be significantly increased.

Reduction of Toxicity, Mobility, and Volume. The use of soil covers or caps does not affect the toxicity or volume of contaminants. Their use does decrease the mobility of the contaminants by providing a barrier to their dissemination as windborne dust as well as providing a barrier to water infiltration.

There is no aspect of this alternative that provides for treatment of the contaminated soil; therefore, this alternative does not satisfy statutory preference for treatment as a principal element of a remedial activity.

Short-term Effectiveness. The protection of the environment, the surrounding community, and workers during implementation of this alternative can be maintained by applying adequate controls during the handling of soil and clay materials. Additional protection of the environment from adverse impact will be ensured by the restoration of the contained areas to near-natural conditions by planting vegetation over the covers or caps.

The time required to implement this alternative is estimated at three months.

Implementability. The technical feasibility of the actions involved in the implementation of this alternative has been demonstrated. Materials and services for the installation of soil covers and engineered caps are readily available. Their installation is performed with conventional earth moving, loading, and compaction equipment and little or no specialized expertise is required.

Cost. Cost estimates developed for this alternative were made based on engineering calculations, vendor estimates, other documented sources, and experience. A summary of capital and O&M costs for the implementation of the various options of Alternative 2 is presented in Table 4-1. A detailed breakdown of these costs is provided in Appendix C.

4.2.4 Alternative 3: On-Site Treatment by Solidification/Stabilization

4.2.4.1 Description of Alternative. The core of this alternative involves the on-site treatment of all excavated contaminated soils by solidification/stabilization. In addition, options are presented that make use of soil washing to reduce the volume of soil to be subjected to solidification/stabilization. Other options reflect the ultimate disposal of the treated solids including: (1) on-site disposal in the existing active landfill; (2) on-site disposal in a new landfill; and (3) off-site disposal in a solid waste landfill.

A discussion of the soil washing process is provided in Section 4.2.1.4, Soil Washing to Reduce Contaminated Soil Volume. The solidification/stabilization process is described in Section 4.2.1.5, Solidification/Stabilization. A description of on-site disposal of

Table 4-1. Alternative 2: Institutional Control and Containment

Element	Alternative Option (1993 Dollars)	
	2A	2B
Capital Cost		
Fence Sites	31,000	31,000
Soil Cover	59,000	
Engineered Cap		116,000
Contingency	23,000	37,000
Total Capital	$113,000	$184,000
O&M Cost		
5 Year Review	6,400	6,400
Contingency	1,600	1,600
Total O&M	8,000	8,000
Remedial Design/Planning	11,000	19,000
Total Cost	**$132,000**	**$211,000**

Source: Arthur D. Little, Inc.

treatment residues is provided in Section 4.2.1.6, On-Site Landfill Disposal of Nonhazardous Soil and/or Treatment Residues. Aspects of the implementation of those processes that are specific to this alternative are discussed below.

Integration of Processes. Schematics of the integration of the various processes and options involved in this alternative are presented in Figures 4-5 and 4-6. For the purposes of this analysis, it is assumed that pretreatment by soil washing (for those options involving pretreatment) will be completed prior to the startup of the solidification/stabilization process. By staging the operations in this manner, operation of the solidification/stabilization process can be conducted independently of soil washing allowing for a continuity of feed to the process.

Procurement, site preparation, and treatability testing required for the solidification/stabilization process can occur during the time of pretreatment by soil washing.

4.2.4.2 NCP Criteria Analysis. The degree to which this alternative satisfies the seven threshold and primary balancing criteria of the NCP is discussed below.

Overall Protection of Human Health and Environment. This alternative would provide for overall protection of human health and the environment and meet the Remedial Action Objectives by immobilizing the contaminants of concern. Solidification/stabilization of contaminated soil would result in immobilization of metals. The degree to which organic contaminants would be immobilized would require determination in treatability testing. The treated product will be removed to a solid waste landfill, which will provide for continued protection of human health and environment.

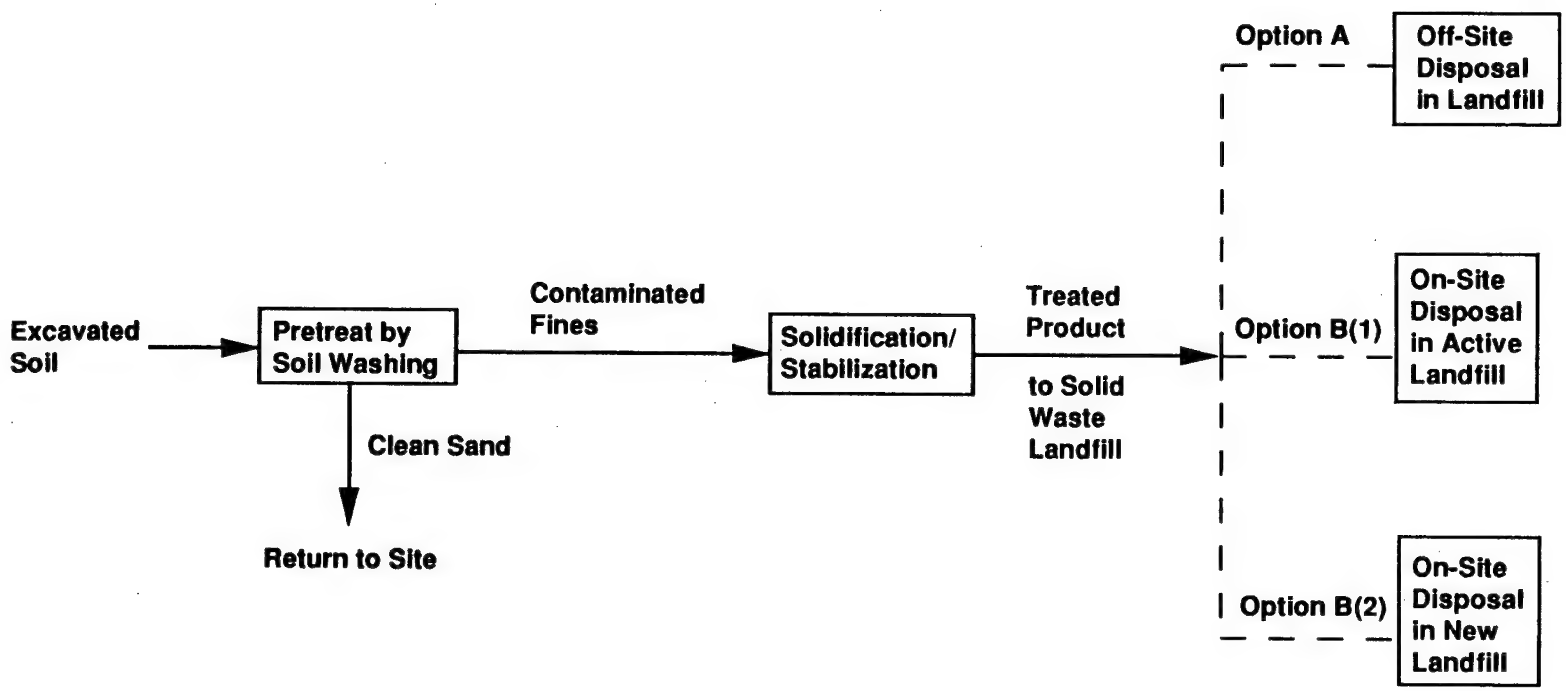
Protection of human health and the environment during remediation would be achieved by:

- Adherence to design and operating controls for each of the remedial processes to optimize performance and minimize emissions
- Isolation of the various remedial activities from populated areas
- Assurance that occupational risks to workers are minimized through proper training and adherence to the site Health and Safety Plan

Compliance with ARARs. Alternative 3 would be expected to meet all ARARs, specifically:

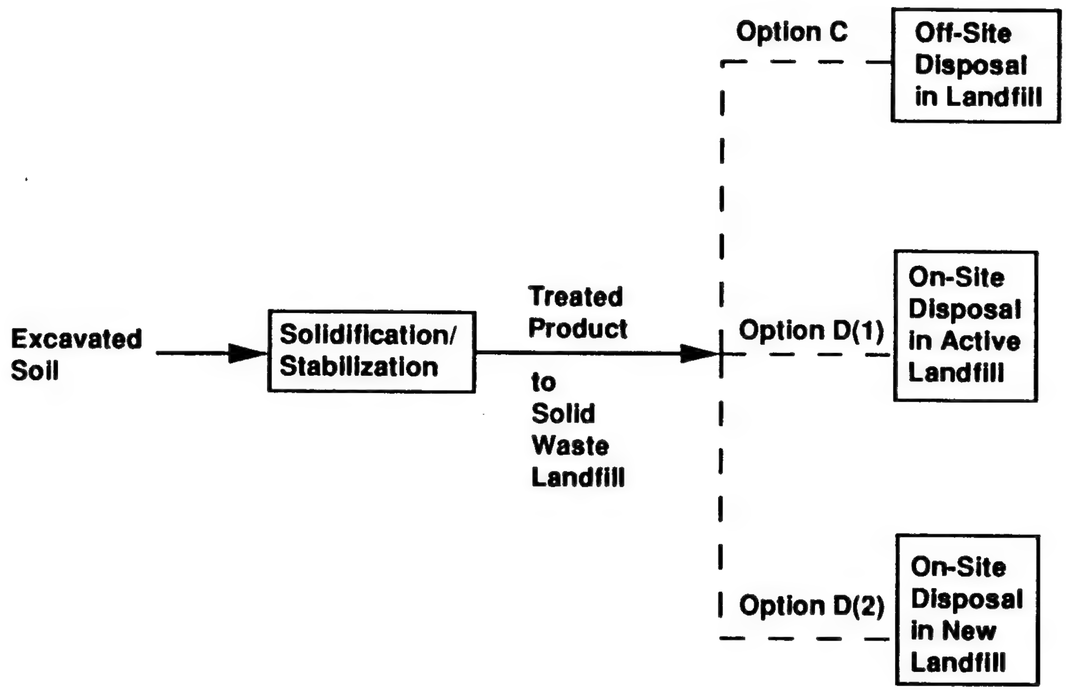
The removal of contaminated soils from the Miscellaneous Sites would meet chemical-specific ARARs at that area. Subsequent treatment by solidification/stabilization would further increase adherence to ARARs by immobilizing metal contaminants. The degree to which the metal contaminants are immobilized would require confirmation through

Figure 4-5: Schematic of Alternative 3 (On-Site Treatment, Solidification/Stabilization) Options A and B



Source: Arthur D. Little, Inc.

Figure 4-6: Schematic of Alternative 3 (On-Site Treatment, Solidification/Stabilization) Options C and D



Source: Arthur D. Little, Inc.

conducting analyses and TCLP of the treated product. The ability of solidification/stabilization to immobilize organic contaminants is less certain but could be confirmed during the conduct of feasibility testing.

The processes involved in Alternative 3 would not be expected to affect protected species present at the UMDA facility, nor affect any off-site designated wetlands.

All actions associated with this alternative can be adequately controlled so that action-specific ARARs can be met. Dust emission sources will be monitored during soil excavation and handling. Disposal of the treated material will be subject to testing to ensure that adequate contaminant immobilization has occurred to conform to requirements under RCRA.

Long-Term Effectiveness and Permanence. Solidification/stabilization will result in immobilization or containment of the metal contaminants. This will reduce the risks and hazards associated with handling and transporting the material. The treated product will be removed from the site and disposed of in a solid waste landfill, which will provide additional protection over the long term. The mobility of organic contaminants after solidification is unknown and would require determination during feasibility/treatability testing.

Reduction of Toxicity, Mobility, or Volume. The solidification/stabilization process considered for use in this alternative will reduce the mobility of metal contaminants. It is assumed that the mobility of organic contaminants will be reduced; however, the degree to which this is true will require determination by treatability testing. The disposal of the treated material in a suitable solid waste landfill will further reduce the potential for contaminant mobility.

The process will not reduce contaminant toxicity and the total volume of waste requiring disposal will be increased due to the solidification/stabilization process.

Short-Term Effectiveness. Remedial operations will involve activities that present potential risks and hazards to workers. These activities include soil excavation and handling, heavy equipment use, and solidification/stabilization process operation. Despite these risks and hazards, adequate worker protection can be maintained through the adherence to site safety plans, standard health and safety protective measures, and monitoring guidelines. Worker protection has been demonstrated for solidification/stabilization in processes remedial activities. Appropriate dust controls will be used to ensure that effects to the environment are not significant.

The isolation of the remedial operations will ensure that the community will be protected from remedial activities including excavation, on-site movement of contaminated materials, and the solidification/stabilization process.

Off-site transport of treated material will present the most significant source of potential exposure to the community. However, the material at this stage is expected to be non-hazardous. In addition, proper equipment for off-site transportation will be used and the material will be covered to prevent release of any of the treated product.

Given this scenario, it is estimated that a total treatment time for contaminated soil without pretreatment (Options C and D) would be approximately 30 days. For Options A and B involving pretreatment by soil washing approximately 250 days would be required for treatment.

Implementability. The use of soil washing as a pretreatment is an innovative technology and, as such, its demonstrated effectiveness is not as well established as other, less innovative technologies. Although solidification/stabilization has proven capable of immobilizing metal contaminants, treatability tests will be required to provide for a final determination of the feasibility of the process on Miscellaneous Sites soils that contain metals and, to a more limited extent, organics. The final treated product will require extensive testing to assure that the maximum potential for contaminant immobility is achieved and can be maintained.

With the exception of soil washing, services and materials for all remedial activities involved in this alternative are readily available. As an innovative technology, there are a limited number of firms that have demonstrated soil washing capabilities. There are several firms that supply transportable, turnkey, systems for complete treatment by solidification/stabilization.

Cost. Cost estimates developed for this alternative were based on engineering calculations, vendor estimates, other documented sources, and experience. The cost of implementation of the solidification/stabilization process will be dependent on the results of treatability tests.

Capital and O&M costs for the implementation of the various options of Alternative 3 are presented in Table 4-2. A detailed cost breakdown in provided in Appendix C.

4.2.5 Alternative 4: On-Site Treatment by Incineration and Solidification/Stabilization

4.2.5.1 Description of Alternative. The core of this alternative includes the use of two primary technologies to treat contaminated soils at the Miscellaneous Sites: incineration and solidification/stabilization. In addition, options are presented that make use of soil washing to reduce the volume of soil to be subjected to the primary treatment technologies.

Table 4-2: Alternative 3: On-Site Treatment - Solidification/Stabilization

Element	Alternative Option (1993 Dollars)					
	3A	3B(1)	3B(2)	3C	3D(1)	3D(2)
Capital Cost						
Excavate/Haul Soil	67,000	67,000	67,000	67,000	67,000	67,000
Soil Washing	367,000	367,000	367,000			
Solidification/Stabilization	73,000	73,000	73,000	87,000	87,000	87,000
Off-Site Landfill	76,000			378,000		
On-Site Landfill - Active		5,000			24,000	
On-Site Landfill - New			1,305,000			1,323,000
Site Reclamation	55,000	55,000	55,000	55,000	55,000	55,000
Contingency	159,000	141,000	466,000	146,000	58,000	383,000
Total Capital	$797,000	$708,000	$2,333,000	$733,000	$291,000	$1,915,000
O&M Cost						
Soil Washing	270,000	270,000	270,000			
Solidification/Stabilization	121,000	121,000	121,000	343,000	343,000	343,000
Five Year Review		6,000	6,000		6,000	6,000
Contingency	98,000	99,000	99,000	86,000	87,000	87,000
Total O&M	$489,000	$496,000	$496,000	$429,000	$436,000	$436,000
Remedial Design/Planning	$129,000	$121,000	$283,000	$116,000	$73,000	$235,000
Total Cost	**$1,415,000**	**$1,325,000**	**$3,112,000**	**$1,278,000**	**$800,000**	**$2,586,000**
Treatment Cost per CY	**288**	**270**	**634**	**260**	**163**	**527**

Note: Costs are based on cleanup to Residential 1x10-6 level

Source: Arthur D. Little, Inc.

Rotary kiln incineration is used to treat soils (and/or fines) contaminated with both metals and organic contaminants (pesticides and explosives). A solidification/stabilization process will be used to treat incinerator residues (ash and particulate removed in the air pollution control system) and soils (and/or fines) contaminated with metals only. Once analysis of the treated material has verified the effectiveness of the treatment in meeting established standards, the treated material would be disposed of: (1) off site in a solid waste landfill; (2) on site in the existing active landfill; or (3) on site in a new landfill. Schematics of the integration of the processes and various options associated with this alternative are presented in Figures 4-7 and 4-8.

A discussion of the soil washing process is provided in Section 4.2.1.4, Soil Washing to Reduce Contaminated Soil Volume. The solidification/stabilization process is described in Section 4.2.1.5, Solidification/Stabilization. The incineration process is described below.

Incineration. Based on an economic analysis performed for the Army, the use of a transportable incinerator as opposed to a field erected incinerator is generally more cost effective at sites with less than 130,000 yd^3 of soil to be treated[35]. Since transportable rotary kiln incinerators have been used successfully in full-scale remediations of explosive-contaminated soil at two Army installations, such a system will form the basis of the incineration portion of this alternative.

Transportable incineration systems are available in a range of sizes with varying feed rates. This analysis will assume that a transportable unit with a nominal feed rate of 4 tons/hr will be used.

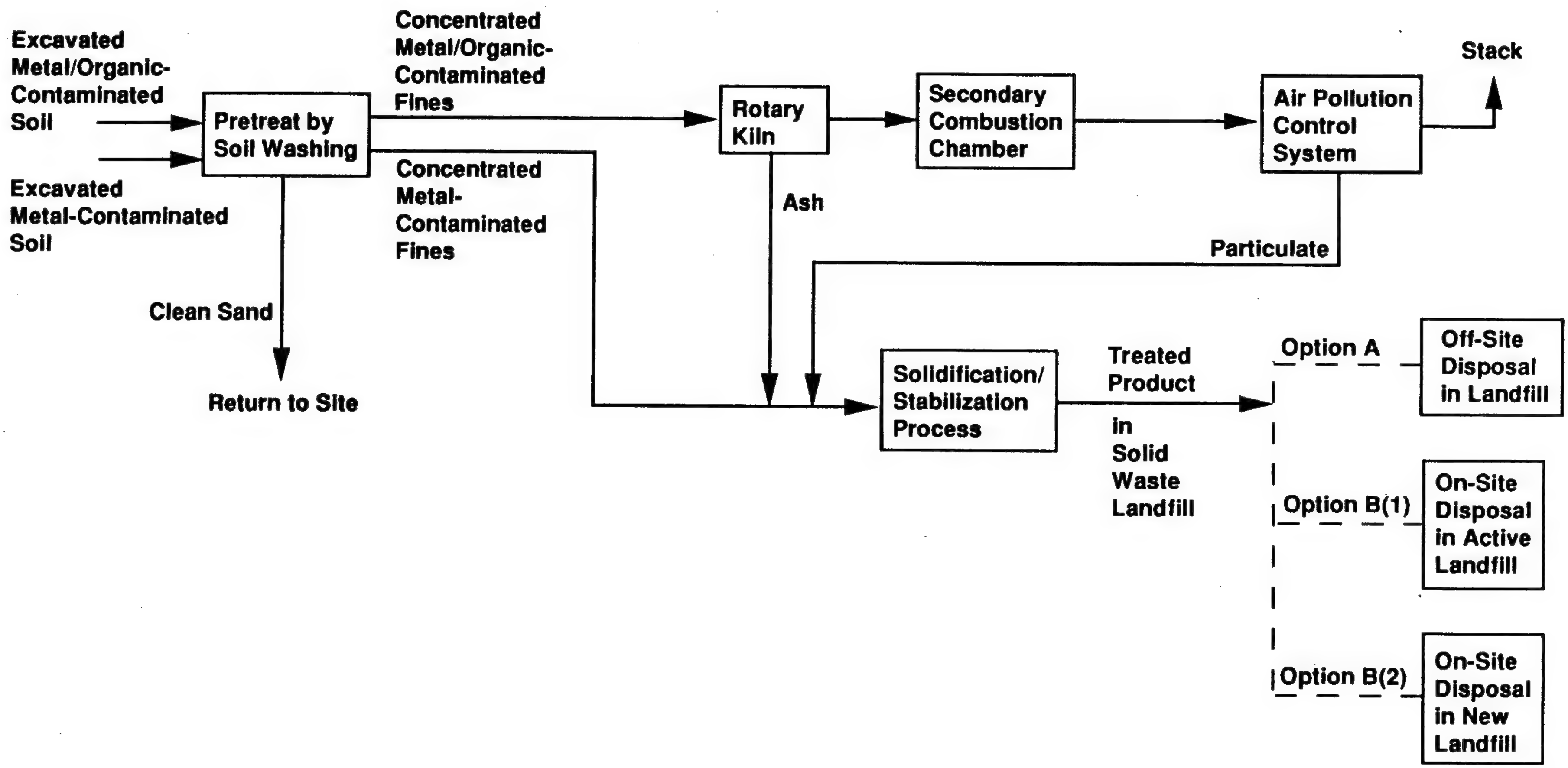
The transportable incineration system consists of the following elements:

- Feed system
- Incineration system including a primary chamber (kiln) and a secondary chamber(afterburner)
- Air pollution control system
- Ash collection and handling system

Feed System. Once excavated, the contaminated soil would be placed on a temporary storage pad in the feed staging area. The stockpiled soil would be covered to protect it from precipitation and to prevent its dispersion by wind.

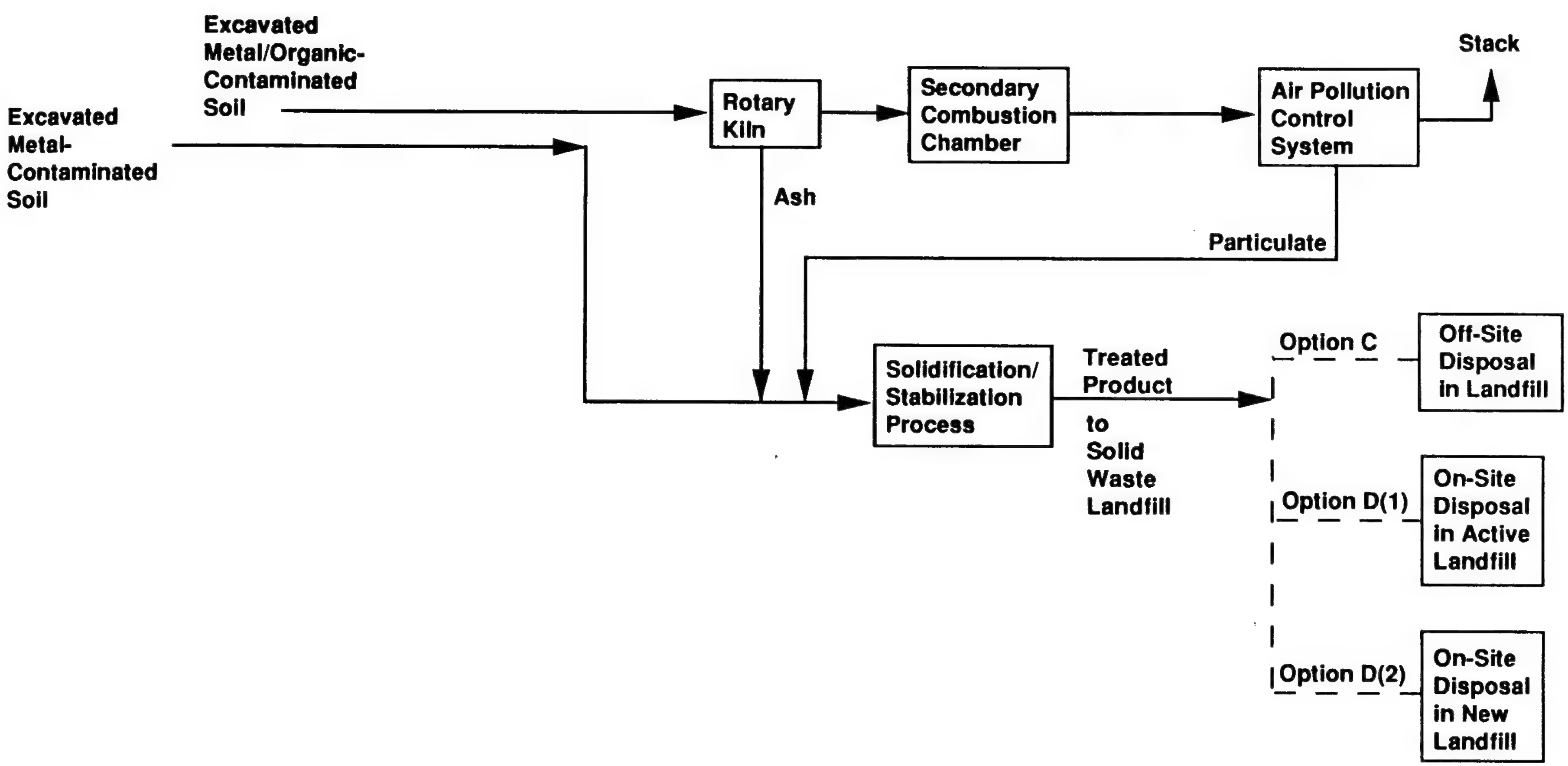
Large rocks and debris would be screened as necessary to preclude damage to the incinerator equipment. Removed rocks or debris would be washed with water to remove any contaminated soil. The volume of washwater generated in this manner is expected to be very low compared to the total volume of incinerator feed, and may therefore be incorporated into the feed with little or no impact on the incineration process.

Figure 4-7: Schematic of Alternative 4 (On-Site Treatment: Incineration and Solidification/Stabilization) Options A and B



Source: Arthur D. Little, Inc.

Figure 4-8: Schematic of Alternative 4 (On-Site Treatment: Incineration and Solidification/Stabilization) Options C and D



Source: Arthur D. Little, Inc.

From the storage pad, the soil would be staged by bulk loading equipment to the incinerator feed area. Since explosives will be present in the feed material, care will be required to eliminate any potential for accumulation or confinement of explosives. This analysis assumes a representative feed system consisting of a metered live bottom hopper; a screw or belt conveyor to transfer the soil from the hopper to the kiln feed system; and a screw or belt conveyor to feed the soil into the kiln.

Incineration System. The primary chamber of the incineration system is the rotary kiln, a rotating, refractory-lined, cylindrical vessel mounted at a slight incline to the horizontal.

The kilns are designed to provide a sufficient residence time to effectively treat the soil. Design factors that specify the residence time include the soil feed rate, kiln rotation rate, and the physical dimensions of the kiln.

The kiln is typically designed for steady-state operation at 1,200°F to 1,800°F. A control system is typically used to automatically maintain primary combustion chamber temperatures within the design range for the particular waste to be treated. A minimum of 100 percent excess air is typical.

The secondary chamber, or afterburner, is a stationary, refractory-lined cylinder. The afterburner design temperatures are higher than those for the kiln, in a range of 1,700 to 2,400°F. As with the kiln, temperatures in the secondary chamber are controlled automatically. A minimum of 100 percent excess air is usually input to the secondary chamber. Hot gases from the secondary chamber are typically quenched to reduce their temperature prior to further treatment.

Air Pollution Control (APC) System. The incinerator APC system is composed of wet and/or dry scrubbing processes designed to remove products of incomplete combustion, particulates, and acid gases from the flue gas exiting the secondary combustion chamber. An example of a wet scrubbing system is a venturi scrubber charged with lime or caustic and water solutions. When the contaminants to be removed are nonhalogenated, these systems are typically designed so that the aqueous wastes from the scrubber can be neutralized, filtered, and recycled, thereby minimizing or eliminating wastewater discharges A dry scrubbing system often uses a fabric filter to catch solids and particulate.

It is assumed that any incinerator selected to remediate the soils at the Miscellaneous Sites would be equipped with an APC system that would meet local, state, and federal air emissions standards.

Ash Handling and Collection System. The solids that exit the primary and secondary combustion chambers are referred to as ash. The ash is typically collected using a wet ash system in which the hot ash exiting the chambers is quenched with water. Excess water may be recycled to minimize wastewater discharges.

Since all of the contaminated soil contains metals, the ash (including solids from the kiln and particulates from the APC system) will be subjected to solidification/stabilization prior to final disposition.

Site Suitability. The selection of the incineration site would be based on the following:

- The site needs to contain sufficient land area to provide a concentric ring of unoccupied space as a buffer zone between the excavation and incineration areas, and the nearest area of human activity.
- Access roads must be available and capable of supporting the 60,000 lb incinerator trailers and heavy earthmoving equipment.
- Accessibility to the waste feed material must be direct and unencumbered.

Temporary covers would be provided for the contaminated soil and the treated soil stockpiled in the holding area.

Based on the above, the total area requirements for the 4 ton per hour incineration system would be approximately 87,000 ft^2 (2 acres).

In addition to the area actually required for the incineration system, access roads would be required to connect the treatment area with existing roads.

Utilities. Utility requirements for operation of the incineration system described above include:

- A continuous water supply to furnish charge and makeup water to the scrubber system. Evaporative losses are assumed to be approximately 70 gpm. For the purposes of analysis, it is assumed that this water will be available from installation sources. However, if supplies at the treatment site are insufficient, an alternate supply (from on or off the installation) will be required.
- Electrical service of 2,000 kVA, 480 V, and 3 phases is required as the power source for the primary combustion chamber, fans and pumps. In addition, the operation of ancillary operation and support systems will require 15 amp, 120-V, 1-phase service. For the purposes of this analysis, it is assumed that these electrical requirements can be met on the installation.

- Propane equivalent to about 4 million BTU/hr. This will have to be brought onto the site as it is unavailable at the installation.

- Water treatment chemicals, as required.

- Fuel oil for feed heating value improvement, as necessary.

Personnel. The total number of operating personnel required for such a transportable incineration system is 30 to 35. These numbers include process operators, supervisors including a shift foreman, a maintenance supervisor, construction operators (as required), administrative staff and a project manager. Operations are conducted in 2 or 3 shifts, 24-hours per day, 7 days per week.

Performance Testing. Waste characterization and treatability testing are necessary to establish the suitability of the contaminated soil feed and the range of recommended operating parameters for the incineration system. This will ensure optimum incinerator performance to maintain regulatory compliance. Test phases required include:

- Laboratory analysis of waste feed. Required to evaluate physical and chemical properties critical to the operation of the incineration system (including feed preparation, feed to incinerator, incineration, air pollution control, and residue management). Such properties include density, moisture content, heating value, ash content, particle size, organic and inorganic species identification and quantification.

- Trial burn in accordance with regulatory requirements to ensure that required operating and emission standards are attainable and maintained.

Implementation and treatment time. For the purpose of this analysis, it is assumed that one year is required to complete all preparations (including procurement) prior to mobilizing the incinerator system on site. A transportable system will require three to eight weeks to mobilize[38].

The time required to conduct and analyze trial burns will be dependent on the specific regulatory requirements and, in some cases, initial results. A typical RCRA trial burn would include three 4-hour burns. For the purposes of this analysis, it is assumed that the entire trial burn period will require approximately four weeks; this includes planning, preparing, conducting the trial burn and analyzing the results.

Integration of Processes. For the purposes of this analysis, it is assumed that incineration of the explosive and pesticide contaminated soil will be completed prior to the startup of the solidification/stabilization process. By staging the operations in this manner, operation of the solidification/stabilization process can be conducted independently of incineration, allowing for a continuity of feed to the process.

Procurement, site preparation, and treatability testing required for the solidification/stabilization process can occur during the time of operation of the incinerator.

4.2.5.2 NCP Criteria Analysis. The degree to which this alternative satisfies the seven threshold and primary balancing criteria of the NCP is discussed below.

Overall Protection of Human Health and Environment. This alternative would provide for overall protection of human health and the environment and meet the Remedial Action Objectives by destroying or immobilizing the contaminants of concern. Incineration of the organic-contaminated soil would result in at least a 99.99 percent reduction in contaminants with final concentrations below detection limits. Solidification/stabilization of metals-contaminated soil and incinerator residues would result in immobilization of metals. The treated product will be removed to a solid waste landfill, which will provide for continued protection of human health and environment.

Protection of human health and the environment during remediation would be achieved by:

- Adherence to design and operating controls for each of the remedial processes to optimize performance and minimize emissions
- Isolation of the various remedial activities from populated areas
- Assurance that occupational risks to workers are minimized through proper training and adherence to the site Health and Safety Plan

Compliance with ARARs. Alternative 4 would be expected to meet all ARARs. Removal of contaminated soils from the Miscellaneous Sites will allow ARARs to be met at those sites. Furthermore, incineration and solidification/stabilization would be expected to meet the requirements for reduction of contaminants to background levels, whether it be by contaminant destruction (incineration) or immobilization (solidification/stabilization). This would require confirmation through conducting analyses and TCLP with the resulting product from the solidification/stabilization process.

The processes involved in Alternative 4 would not be expected to affect protected species present at the UMDA facility, nor affect any off-site designated wetlands.

Incineration has been proven for the destruction of explosives and pesticides. Given the relatively low concentrations of these contaminants in Miscellaneous Sites soils, it is expected that the treatment standards can be met. Air emissions from all operations involved in the remediation are expected to meet their respective ARARs providing that operating and control procedures are maintained in accordance with established

guidelines. Monitoring of emissions from the incinerator stack will be conducted to ensure compliance.

Long-Term Effectiveness and Permanence. Incineration of organic-contaminated soil has proven successful in meeting required process efficiencies and performance specifications. The organic contaminants are destroyed in incineration and therefore, represent no short- or long-term hazards. Residues from the incineration process are further treated to immobilize metal contaminants, increasing the assurance that the incinerated material poses no risks or hazards from any residual organic contaminants. All treated materials and residues are removed from the site so no associated risks will remain at the site.

Solidification/stabilization will result in immobilization or containment of the metal contaminants in soil and incinerator residues. This will reduce the risks and hazards associated with handling and transporting the material. The treated product will be removed from the site and disposed of in a suitable solid waste landfill which will provide additional protection over the long term.

Reduction of Toxicity, Mobility, or Volume. Because incineration of the organic-contaminated soil will result in a destruction of the organic contaminants, a reduction in contaminant toxicity is expected. In addition, incineration will moderately reduce the total volume of organic-contaminated waste.

Solidification/stabilization will reduce the mobility of the metal contaminants. The disposal of the treated material in a suitable solid waste landfill will further reduce the potential for contaminant mobility. The process will not reduce contaminant toxicity and the total volume of waste will be increased due to the solidification/stabilization process.

Short-Term Effectiveness. Remedial operations will involve activities that present potential risks and hazards to workers. These activities include soil excavation and handling, heavy equipment use, incinerator operation, and solidification/stabilization process operation. Despite these risks and hazards, adequate worker protection can be maintained through the adherence to site safety plans, standard health and safety protective measures, and monitoring guidelines. Worker protection has been demonstrated for all of the operations in previous remedial activities.

The isolation of the remedial operations will ensure that the community will be protected from remedial activities including excavation, on-site movement of contaminated materials, and the solidification/stabilization process. This isolation, when combined with adherence to proper operating conditions of the incineration and ancillary air pollution control processes, further assures community protection.

Off-site transport of treated material will present the most significant source of potential exposure to the community. However, the material at this stage is expected to be non-

hazardous. In addition, proper equipment for off-site transportation will be used and the material will be covered to prevent release of any of the treated product.

By pursuing this alternative, the remedial response objectives for the entire Miscellaneous Sites will be achieved within one year.

Implementability. The use of soil washing as a pretreatment is an innovative technology and, as such, its demonstrated effectiveness is not as well established as other, less innovative, technologies. The technical feasibility of the incineration of organic-contaminated soil has been demonstrated and documented. Although solidification/stabilization has proven capable of immobilizing metal contaminants, treatability tests will be required to provide for a final determination of the feasibility of the process on soils and incinerator residues. The final treated product will require extensive testing to assure that the maximum potential for contaminant immobility is achieved and can be maintained.

With the exception of soil washing, services and materials for all remedial activities involved in this alternative are readily available. As an innovative technology, there are a limited number of firms that have demonstrated soil washing capabilities. A number of firms provide capabilities for mobilizing, operating, and demobilizing transportable incinerator systems. An increasing number of firms supply transportable, turnkey, systems for complete treatment by solidification/stabilization.

Cost. Cost estimates developed for this alternative were made based on engineering calculations, vendor estimates, other documented sources, and experience. The cost of implementation of the solidification/stabilization process will be heavily dependent on the results of treatability studies. As a result, associated costs should be considered as preliminary estimates.

Capital and O&M costs for the implementation of the various options of Alternative 4 are presented in Table 4-3. A detailed cost breakdown is provided in Appendix C.

4.2.6 Alternative 5: On-Site Solidification/Stabilization and Off-Site Incineration

4.2.6.1 Description of Alternative. The core of this alternative includes the use of two primary technologies to treat contaminated soils at the Miscellaneous Sites: incineration and solidification/stabilization (as was the case with Alternative 4). The difference between Alternative 4 and Alternative 5 is that the incineration of soils containing only organic contaminants (pesticides and explosives) occurs off site in Alternative 5. An on-site stabilization/solidification process will be used to treat soil contaminated with metals. Once an analysis of treated material has verified the effectiveness of the solidification/stabilization process in meeting established standards,

Table 4-3: Alternative 4: On-Site Treatment - Incineration and Solidification/Stabilization

Element	Alternative Option (1993 Dollars)					
	4A	4B(1)	4B(2)	4C	4D(1)	4D(2)
Capital Cost						
Excavate/Haul Soil	67,000	67,000	67,000	67,000	67,000	67,000
Soil Washing	351,000	351,000	351,000			
Incineration	292,000	292,000	292,000	659,000	659,000	659,000
Solidification/Stabilization	73,000	73,000	73,000	84,000	84,000	84,000
Off-Site Landfill	66,000			327,000		
On-Site Landfill - Active		4,000			20,000	
On-Site Landfill - New			1,304,000			1,320,000
Site Reclamation	55,000	55,000	55,000	55,000	55,000	55,000
Contingency	226,000	210,000	535,000	298,000	221,000	546,000
Total Capital	$1,130,000	$1,052,000	$2,677,000	$1,490,000	$1,106,000	$2,731,000
O&M Cost						
Soil Washing	270,000	270,000	270,000			
Incineration	250,000	250,000	250,000	528,000	528,000	528,000
Solidification/Stabilization	113,000	113,000	113,000	305,000	305,000	305,000
Five Year Review		6,000	6,000		6,000	6,000
Contingency	158,000	160,000	160,000	208,000	210,000	210,000
Total O&M	$791,000	$799,000	$799,000	$1,041,000	$1,049,000	$1,049,000
Remedial Design/Planning	$192,000	$185,000	$348,000	$253,000	$216,000	$378,000
Total Cost	**$2,113,000**	**$2,036,000**	**$3,824,000**	**$2,784,000**	**$2,371,000**	**$4,158,000**
Treatment Cost per CY	**430**	**415**	**779**	**567**	**483**	**847**

Note: Costs are based on cleanup to Residential, 1x10-6 level

Source: Arthur D. Little, Inc.

the treated material would be transported to: (1) an off-site solid waste landfill for disposal; (2) the existing on-site active landfill for disposal; or (3) a new on-site landfill for disposal.

A discussion of the solidification/stabilization process is provided in Section 4.2.1.5, Solidification/Stabilization. The off-site treatment by incineration involves analysis of the soil, completing required manifests, and transporting the soil off-site and is discussed in greater detail in Section 4.2.7, Off-Site Treatment and Disposal.

A schematic of the integration of the processes and various options associated with Alternative 5 is presented in Figure 4-9.

For the purpose of this analysis, it is assumed that the excavation, analysis, and transport of the soils containing organics only for off-site treatment will be completed prior to the startup of the solidification/stabilization process. Procurement, site preparation, and treatability testing required for the solidification/stabilization of soil containing metals can occur during the time of off-site treatment of the organic-contaminated soil. Soil treated off site will remain off site, it will not be returned to UMDA for disposal.

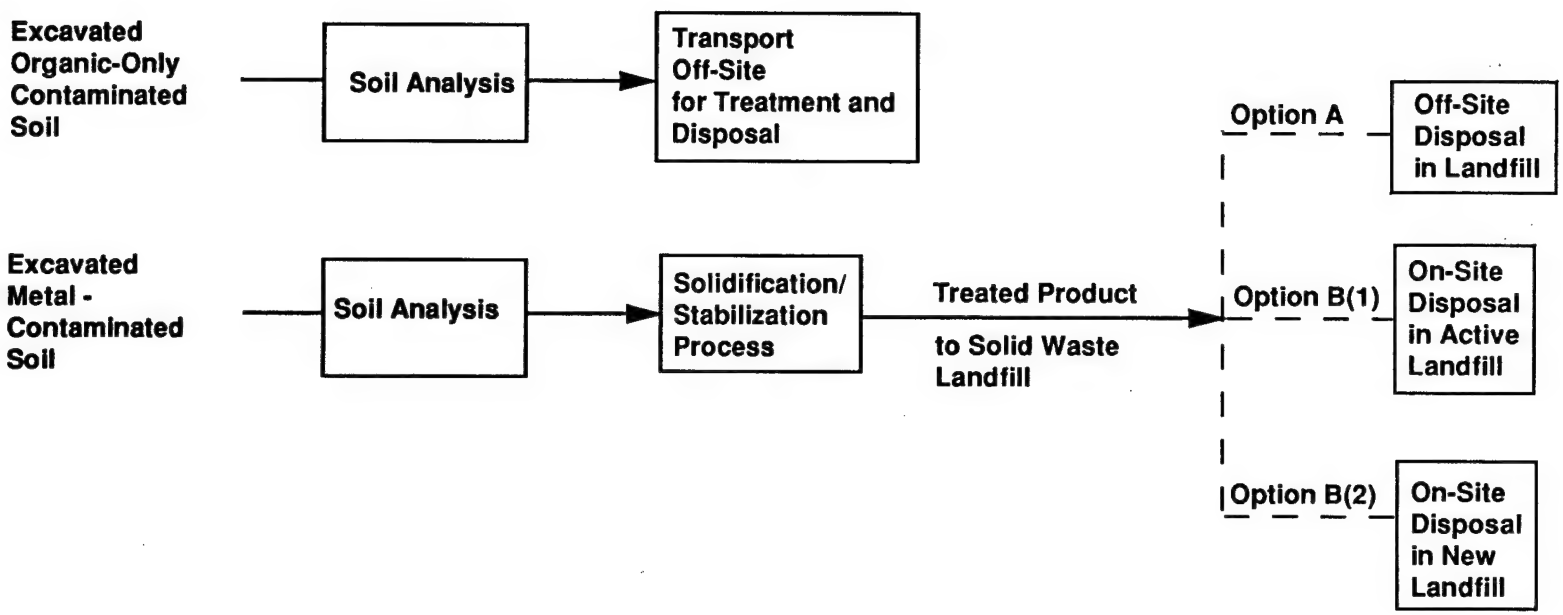
4.2.6.2 NCP Criteria Analysis. The degree to which this alternative satisfies the threshold and primary balancing criteria of the NCP is discussed in the following sections.

Overall Protection of Human Health and Environment. This alternative would provide for overall protection of human health and the environment and meet the Remedial Action Objectives by destroying or immobilizing the contaminants of concern. Off-site incineration of the organic-contaminated soil would result in at least a 99.99 percent reduction in contaminants with final concentrations below detection limits. Solidification/stabilization of metals-contaminated soil and incinerator residues would result in immobilization of metals. The treated product would be removed to a solid waste landfill, which will provide for continued protection of human health and environment.

Protection of human health and the environment during remediation would be achieved by:

- Adherence to design and operating controls for each of the remedial processes to optimize performance and minimize emissions
- Isolation of the various remedial activities from populated areas
- Assurance that occupational risks to workers are minimized through proper training and adherence to the site Health and Safety Plan

Figure 4-9: Schematic of Alternative 5 (Off-Site Treatment: Off-Site Incineration and On-Site Solidification/Stabilization) Options A and B



Source: Arthur D. Little, Inc.

Compliance with ARARs. Alternative 5 would be expected to meet all ARARs. Off-site incineration and solidification/stabilization would be expected to meet the requirements for reduction of contaminants to background levels whether it be by contaminant destruction (incineration) or immobilization (solidification/stabilization). This would require confirmation through conducting analyses and TCLP with the product from the solidification/stabilization process.

The processes involved in Alternative 5 would not be expected to affect protected species present at the UMDA facility, nor affect any off-site designated wetlands.

Incineration has been proven for the destruction of explosives and pesticides. Given the relatively low concentrations of these contaminants in Miscellaneous Sites soils, it is expected that the treatment standards can be met. Air emissions from all operations involved in the remediation are expected to meet their respective ARARs providing that operating and control procedures are maintained in accordance with established guidelines. Monitoring of emissions from the incinerator stack will be conducted to ensure compliance.

Long-Term Effectiveness and Permanence. Incineration of the organic-contaminated soil has proven successful in meeting required process efficiencies and performance specifications. The organic contaminants are destroyed in incineration and therefore, represent no short- or long-term hazards.

Solidification/stabilization will result in immobilization or containment of the metal contaminants in the soil. This will reduce the risks and hazards associated with handling and transporting the material. The treated product will be removed from the site and disposed of in a suitable solid waste landfill, which will provide additional protection over the long-term.

Reduction of Toxicity, Mobility, or Volume. Because off-site incineration of the organic-contaminated soil will result in a destruction of the organic contaminants, a reduction in contaminant toxicity is expected. In addition, incineration will moderately reduce the total volume of waste.

Solidification/stabilization will reduce the mobility of the metal contaminants. The disposal of the treated material in a suitable solid waste landfill will further reduce the potential for contaminant mobility. The process will not reduce contaminant toxicity and the total volume of waste will be increased.

Short-Term Effectiveness. Remedial operations will involve activities that present potential risks and hazards to workers. These activities include soil excavation and handling, heavy equipment use, off-site incinerator operation, and solidification/stabilization process operation. Despite these risks and hazards, adequate

worker protection can be maintained through adherence to site safety plans, standard health and safety protective measures, and monitoring guidelines. Worker protection has been demonstrated for all of the operations in previous remedial activities.

The isolation of the remedial operations will ensure that the community will be protected from remedial activities including excavation, on-site movement of contaminated materials, and the solidification/stabilization process. This isolation, when combined with adherence to proper operating conditions of the incineration and ancillary air pollution control processes, further assures community protection.

Off-site transport of treated material will present the most significant source of potential exposure to the community. Proper equipment for off-site transportation will be used and the material will be contained to prevent release of any contaminated material.

By pursuing this alternative, the remedial action objectives for the entire Miscellaneous Sites Operable Unit will be achieved within one year.

Implementability. The technical feasibility of the off-site incineration of organic-contaminated soil has been demonstrated and documented. Although solidification/stabilization has proven capable of immobilizing metal contaminants, treatability tests will be required to provide for a final determination of the feasibility of the process on soils that contain metals and small concentrations of organics. The final treated product will require extensive testing to assure that the maximum potential for contaminant immobility is achieved and can be maintained.

Services and materials for all remedial activities involved in this alternative are readily available. There are a number of off-site incineration facilities that can accept organic-contaminated soil. An increasing number of firms supply transportable, turnkey, systems for complete treatment by solidification/stabilization.

Cost. Cost estimates developed for this alternative were made based on engineering calculations, vendor estimates, other documented sources, and experience. The final cost of implementation of the solidification/stabilization process will be dependent on the results of treatability tests. As a result, associated costs should be considered as preliminary estimates.

Capital and O&M costs for the implementation of the various options of Alternative 5 are presented in Table 4-4. A detailed cost breakdown is provided in Appendix C.

4.2.7 Alternative 6: Off-Site Treatment and Disposal

4.2.7.1 Description of Alternative. The implementation of this alternative involves the excavation of soil (as described in Section 4.2.1.3, Soil Excavation), segregation of hazardous and nonhazardous soils, transportation of these soils off site for

Table 4-4: Alternative 5: Off-Site Treatment and On-Site Treatment

Element	Alternative Option (1993 Dollars)		
	5A	5B(1)	5B(2)
Capital Cost			
Excavate/Analyze/Haul Soil	76,000	76,000	76,000
Haul and Treat Organic-Only Contaminated Soil Off-Site	791,000	791,000	791,000
Solidification/Stabilization	85,000	85,000	85,000
Off-Site Landfill	338,000		
On-Site Landfill - Active		37,000	
On-Site Landfill - New			1,337,000
Site Reclamation	55,000	55,000	55,000
Contingency	336,000	261,000	586,000
Total Capital	$1,681,000	$1,305,000	$2,930,000
O&M Cost			
Solidification/Stabilization	314,000	314,000	314,000
Five Year Review	6,000	6,000	6,000
Contingency	80,000	80,000	80,000
Total O&M	$400,000	$400,000	$400,000
Remedial Design/Planning	$208,000	$171,000	$333,000
Total Cost	**$2,289,000**	**$1,876,000**	**$3,663,000**
Treatment Cost per CY	**466**	**382**	**746**

Note: Costs are based on cleanup to Residential, 1x10-6 level

Source: Arthur D. Little, Inc.

the treatment of the hazardous soil, and landfill disposal of the nonhazardous soil. A general schematic of this alternative is presented in Figure 4-10.

In this alternative, the soils from the various Miscellaneous Sites requiring soil remediation will be analyzed to determine their hazardous characteristics with respect to the presence of toxic concentrations of metals (i.e., lead). If this alternative is selected, additional sampling of soils before excavation should be collected during the remedial design to characterize the soils as hazardous or nonhazardous to minimize the stockpiling of soils during operation. If the soils are determined to be nonhazardous, they will be transported off-site for disposal at a solid waste landfill facility. If the soils are hazardous, they will be transported off site for treatment at a permitted Treatment, Storage, and Disposal Facility (TSDF). The latter action will require the preparation of manifests for the transport of hazardous material before the soils can be transported off site.

Personnel requirements for the implementation of this alternative are minimal. Personnel will be required to excavate the soil; conduct sampling and analysis of the soil samples; prepare manifests as necessary; and load the excavated soil for transport off site. It is estimated that eight personnel would be required for these activities and each would operate on a one-shift, ten hour per day, five days per week, schedule.

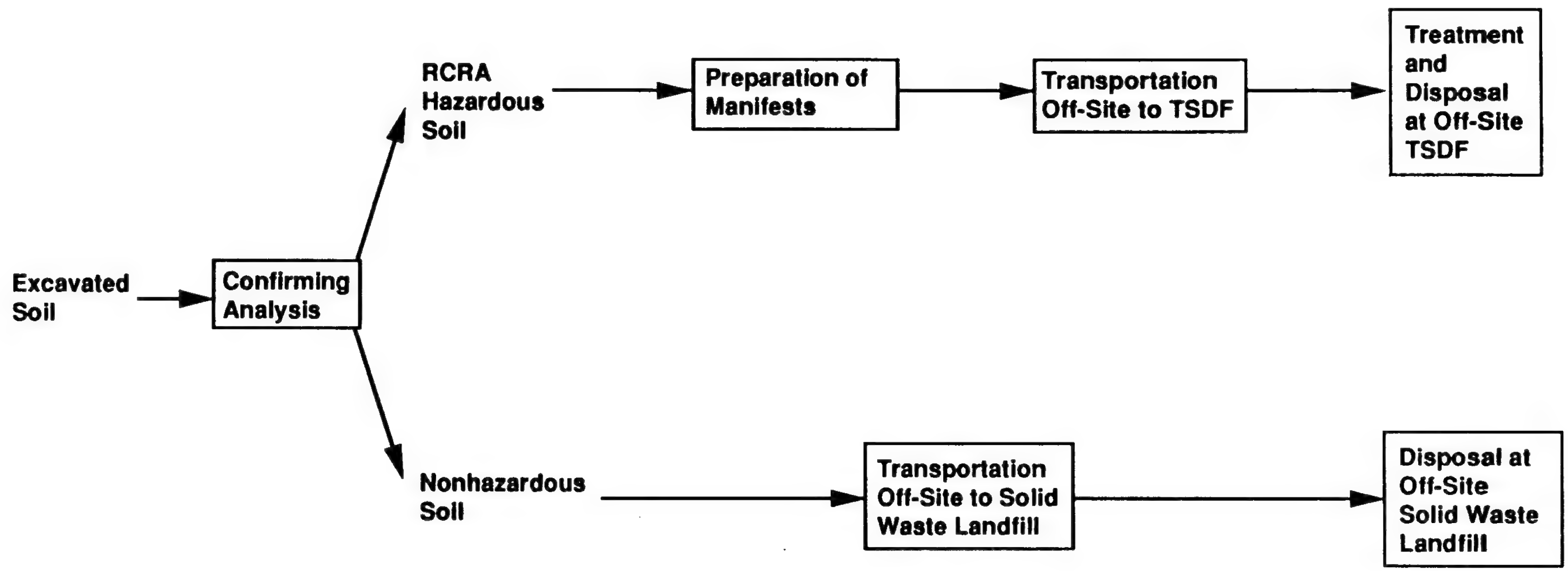
Personnel exposed to contaminated soil are subject to Occupational Safety and Health Administration (OSHA) requirements for hazardous waste site operations (29 CFR 1910.120), including requirements for personal protective equipment as dictated by the specific site conditions and contaminants; physical examinations; and hazardous waste site training.

4.2.7.2 NCP Criteria Analysis. The degree to which this alternative satisfies the seven threshold and primary balancing criteria of the NCP is discussed in the following sections.

Overall Protection of Human Health and the Environment. The implementation of Alternative 6 would provide for overall protection of human health and the environment and meet the remedial action objectives by removing contaminated soil that is the source of unacceptable risks and hazards from UMDA.

Treatment of some of the contaminated soil off site will enhance the protection of human health and the environment, and a properly designed and constructed landfill would provide some reduction of mobility (i.e., a liner and cap) of the balance of the contaminated soil. As a result of lack of treatment, no reduction in toxicity or volume of contaminants will occur. However, this lack of treatment does not satisfy statutory preference for treatment as a principal element of a remedial activity.

Figure 4-10: Schematic of Alternative 6 (Off-Site Treatment and Disposal)



(TSDF - Hazardous Waste Treatment, Storage, Disposal Facility)

Source: Arthur D. Little, Inc.

Near-term protection of the public health and the environment during remediation would be achieved directly by using specific design and operating controls to minimize fugitive dust emissions. Indirect protection would also be afforded by the distance from the Miscellaneous Sites to populated areas.

Occupational risks to on-site workers are expected to be minimized through the use of specific operating controls and procedures and appropriate training. Occupational risks would be addressed in the project Health and Safety Plan.

Compliance with ARARs. This alternative will comply with the health- and risk-based chemical-specific ARARs because all contaminated soil not in compliance with these ARARs will be removed from the Miscellaneous Sites. Soil exhibiting the toxicity characteristic will be treated in accordance with RCRA requirements.

This alternative would comply with location-specific ARARs as it is not expected that protected species present at UMDA would be affected nor would any off-site designated wetlands be impacted.

This alternative will involve the removal of contaminated soil from the Miscellaneous Sites in accordance with all regulatory and other institutional guidelines. Excavation and handling of soils will be conducted in accordance with guidelines for dust suppression, thus eliminating the threat of atmospheric dispersion of fugitive emissions to downwind receptors. Manifests will be prepared for the off-site transport of contaminated soils.

Long-Term Effectiveness and Permanence. Because contaminated soil would be removed from the Miscellaneous Sites, there will be no unacceptable residual risks at the area. The areas where soil is removed will be refilled and restored to surrounding conditions following remediation. A five-year review will not be required following contaminated soil removal at the Miscellaneous Sites as long as unrestricted cleanup levels are achieved.

Once the contaminated soil has been removed from the Miscellaneous Sites and UMDA, the soil characterized as nonhazardous will be disposed of in a solid waste landfill. It is expected that short- and long-term uncertainties associated with such a disposal will be minimal. Soil characterized as hazardous will be treated accordingly at a TSDF that is permitted to ensure the maximum protection of human health and the environment.

Reduction of Toxicity, Mobility, and Volume. This alternative results in the reduction of the volume of contaminated soils present at the Miscellaneous Sites; however, the removal of these soils does not itself constitute a reduction in volume of contaminated media. Only those soils that exhibit characteristics of a hazardous waste will be treated. It is expected that treatment of these soils would result in a reduction of

mobility of contaminants. Such treatment is unlikely to reduce the toxicity of metal contaminants.

A certain volume of the contaminated soil will not be treated, but contaminant mobility should be reduced by placing the soil in a properly designed and constructed landfill. No reduction in toxicity and volume will occur. Furthermore, this lack of treatment does not satisfy statutory preference for treatment as a principal element of a remedial activity.

Short-Term Effectiveness. The protection of the environment, the surrounding community, and workers during implementation of this alternative can be maintained by applying adequate controls during excavation and by adhering to manifesting requirements and common sense during off-site transport of the contaminated materials. Additional protection of the environment from adverse impact will be ensured by restoration of the Miscellaneous Sites to natural conditions after removal of the contaminated soil.

The implementation of this alternative is expected to be accomplished within a short time. The time to achieve the remedial action objectives is estimated to be approximately three months after contracts are in-place for the receipt of soil at the solid waste landfill facility and the TSDF.

Implementability. This alternative for site remediation is a demonstrated technique. The alternative has a high level of technical feasibility with no technical difficulties or unknowns expected. Equipment and services required for its implementation are readily available from a number of sources.

The level of administrative-related activities from a permitting standpoint is moderate. However, obtaining the necessary coordinations and approvals for off-site transportation, treatment, and disposal may be a barrier to implementation of the alternative.

Cost. The cost of implementing this alternative will be dependent on a number of factors including the location of the TSDF and the solid waste landfill selected to receive the contaminated soil. Capital and O&M costs associated with this alternative are presented in Table 4-5. A detailed cost breakdown is provided in Appendix C.

4.3 Comparative Analysis of Alternatives

The comparative analysis of the six alternatives and options is presented below for each of the NCP evaluation criteria.

4.3.1 Protection of Human Health and the Environment

Alternatives 3, 4, and 5 provide the best potential for effectively protecting human health and the environment. Alternatives 3, 4, and 5 provide for the removal of the

Table 4-5: Alternative 6: Off-Site Treatment and Disposal

Element	Alternative 6 (1993 Dollars)
Capital Cost	
Excavate/Analyze/Haul Soil On-Site	83,000
Haul Soils Off-site	70,000
Treat Hazardous Soils Off-Site (1)	393,000
Off-Site Disposal of Nonhazardous Soils (1)	138,000
Site Restoration	55,000
Contingency	184,000
Total Capital	923,000
O&M Cost	
There are no O&M costs associated with this Alternative	0
Total O&M	0
Remedial Design/Planning	92,000
Total Cost	**1,015,000**
Treatment Cost per CY	**207**

Note: Costs are based on cleanup to Residential, 1x10-6 level

(1) Assumes that 50% of soil is characterized as hazardous; 50% of soil is characterized as nonhazardous

Source: Arthur D. Little, Inc.

contaminated soil followed by treatment to destroy and/or immobilize the contaminants. Following treatment, the treated residuals are placed in a landfill that is, or will be, properly maintained, closed, and monitored. Of the various options associated with Alternatives 3, 4, and 5, those that involve the placement of treatment residuals in an on-site landfill (existing active landfill or a new landfill) provide additional protection to human health and the environment by eliminating the off-site transport and disposal of these materials.

Alternative 6 provides for a moderate level of protection of human health and the environment as it does provide for the treatment of contaminated soils that exhibit the toxicity characteristic. However, soils that do not exhibit the toxicity characteristic and are thus classified as nonhazardous are disposed of, without treatment, in an off-site landfill.

Alternative 2 will increase the potential for protection of human health and the environment by using soil covers or caps placed over the contaminated soils to prevent the dispersion of contaminants in windborne dust and to reduce infiltration. The use of institutional measures to control access and future use activities will further provide a level of protection. However, this alternative does not remove the source of chemical contamination and does not provide for the reduction of toxicity or volume of contaminants. This alternative requires the long-term and permanent application of monitoring, security, and institutional controls.

Alternative 1 would not provide any protection of human health and the environment over the current state of the Miscellaneous Sites. Nothing would be done to prevent exposure to contaminants or the further spread of these contaminants as windborne dust.

4.3.2 Compliance with ARARs

Alternatives 3, 4, 5, and 6 would meet chemical- and action-specific ARARs through a course of:

- Removal of contaminated soil from the Miscellaneous Sites, thereby reducing residual risks to required levels

- Treatment to destroy organic contaminants (Alternatives 4, 5, and 6) or reduce the mobility of metal contaminants (Alternatives 3, 4, 5, and 6), resulting in residuals that conform to regulatory standards

Alternatives 1 and 2 will not meet chemical-specific ARARs that require a reduction in the levels of contaminants in the soil.

4.3.3 Long-Term Effectiveness

Alternatives 3, 4, 5, and 6 would provide for the permanent removal of contaminants from the Miscellaneous Sites. However, uncertainties associated with long-term

effectiveness arise due to the ultimate disposal of treatment residues and/or nonhazardous contaminated soil. For example, the long-term effectiveness of Alternatives 3, 4, and 5 will depend on the effectiveness of the soil treatment technologies and the landfill performance. Alternatives 3, 4, and 5 provide for the lesser degree of uncertainty with respect to ultimate disposal as all contaminated soil is treated and only treatment residues are disposed of. Alternative 6 only provides for the treatment of hazardous soil resulting in the need for landfill disposal of nontreated, nonhazardous soil in addition to treatment residues.

Alternative 2 provides only limited assurance that the actions taken will be effective over the long-term. Soil covers and caps used to contain contamination are typically not considered to be either long-term or permanent solutions to contamination or exposure. The long-term effectiveness of their use at the Miscellaneous Sites, however, is enhanced through the application of access and future use controls.

Alternative 1 does not provide for any actions to be taken and, as such, there is no application of Alternative 1 to this criterion.

4.3.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives 3, 4, 5, and 6 provide for various degrees of reducing the toxicity, mobility, or volume of contaminants through treatment. Alternative 3 will result in the immobilization of contaminants (to be demonstrated in treatability testing), however it will not result in a reduction of contaminant toxicity. By employing the option of soil washing to initially reduce the volume of contaminated soil, this alternative will ultimately result in the reduction of contaminant volume. If the soil washing option is not pursued, the total volume will increase as a result of the solidification/stabilization process. The implementation of Alternatives 4 and 5 will result in the destruction of organic contaminants and the immobilization of metal contaminants (to be demonstrated in treatability testing). As with Alternative 3, the use of soil washing as a pretreatment will result in a decrease in the volume of contaminants. Further decreases in contaminant volume will be achieved in Alternatives 4 and 5 through the incineration of material containing organic contaminants.

Alternative 6 provide does not provide for a reduction in toxicity or volume of contaminants and provides only for a limited reduction in the mobility of contaminants. This alternative provides only for the treatment of contaminated soil that is classified as hazardous because of the presence of lead. Other contaminated nonhazardous soils are untreated. An additional reduction in contaminant mobility may be achieved through the disposal of treatment residues and untreated soil in controlled landfills.

The only means of reducing contaminant toxicity or volume through the application of Alternatives 1 and 2 is through natural attenuation of the contaminants over time. Due to

the persistent nature of the contaminants, there is little possibility that natural attenuation would ever be complete. However, Alternative 2 would result in some reduction in contaminant mobility.

4.3.5 Short-Term Effectiveness

Operations associated with Alternative 2 are not expected to increase the risks to the community since no contaminants will be released to the environment. Risks to workers involved in implementing the alternative would be minimized through the use of engineering controls and personal protective equipment. The maximum effectiveness of Alternative 2 would be achieved within three months.

Alternatives 3, 4, 5, and 6 provide the potential for risks to workers and the community as they involve the removal, handling, treatment, and transport of contaminated soil and treatment residues. Options of Alternatives 3, 4, 5, and 6 that involve the removal of treatment residues and contaminated soil off site for treatment or disposal provide the greatest risk to the community; however, these risks can be minimized through the application of appropriate controls. Risks to workers involved in the various activities of Alternatives 3, 4, 5, and 6 will be minimized through the application of proper engineering controls and the use of personal protective equipment. The maximum effectiveness of Alternatives 3, 4, 5, and 6 can be achieved within approximately one year of their initiation.

4.3.6 Implementability

The technical feasibility of Alternative 2 has been demonstrated. Soil covers and caps have been used for years to provide for containment of a variety of material. Materials and services required to implement Alternative 2 are readily available from a number of sources.

Most of the activities involved in Alternatives 3, 4, 5, and 6 (e.g., soil excavation, soil handling, transport, treatment by solidification/stabilization and/or incineration, and landfill disposal of treatment residues and/or soil) have been demonstrated in remedial applications. Services and materials are readily available for their performance. The use of solidification/stabilization will require that treatability testing be conducted to ensure that it can meet treatment requirements. Options of Alternatives 3 and 4 that involve the use of soil washing as a pretreatment to reduce the volume of contaminated soil introduce a greater degree of uncertainty with respect to technical feasibility and the availability of services and materials. The soil washing process to be used is considered an innovative technology and, as such, there have been fewer demonstrations of its use and the materials and services required for its implementation may be less readily available.

Uncertainties associated with the administrative feasibility of Alternatives 3, 4, 5, and 6 center on those options that involve the transport of treated and untreated materials off site. Adequate coordination between on-site and off-site personnel will be required to ensure that transportation is performed under compliance and with minimum risk of

potential on-site and off-site exposure to contamination. Additional administrative compliance will be required with respect to the operation of the on-site incinerator included as part of Alternative 4.

4.3.7 Cost

The capital and operating costs for each of the alternatives and options are presented in Table 4-6. In addition, a unit volume cost is provided for those alternatives and options that involve treatment of the contaminated soil.

In additional cost presentation has been prepared to reflect the potential for reduction in costs associated with the remedial alternatives and options as a result of cleanup to levels that will permit light industrial use with residual risks imposed by soil of $1x10^{-6}$ and $1x10^{-5}$. These costs are provided in Table 4-7. For reference, the volumes of affected soil for each of these cleanup levels is provided (refer to Section 2.3.2, Estimated Areas and Volumes of Contaminated Media Requiring Remediation). As can be seen in Table 2-7, the contaminated soil volumes for the two light industrial use scenarios ($1x10^{-6}$ and $1x10^{-5}$) are the same. Therefore, the cost to remediate to these levels are the same.

4.3.8 Remediation of Selected Sites

Following a discussion between the Army and regulatory agencies, there appear to be two sites that require remediation based on risk and hazard levels.[43] These sites were identified as those having risks greater than $1x10^{-4}$ (residential), hazard quotients in excess of 2 (residential) or lead levels in excess of 500 µg/g.

Affected areas and volumes requiring remediation to a levels $1x10^{-6}$ (residential and light industrial) for these sites are presented in Table 4-8. Costs developed for each of the remedial alternatives applied to these sites are presented in Table 4-9.

Table 4-6: Summary of Cost of Alternatives

Alternative	Capital Cost ($)	O&M Cost ($)	Remedial Design/Planning ($)	Total Cost ($)	Cost per Unit of Soil ($/cu yd)
1	0	0	0	0	NA
2A	113,000	8,000	11,000	132,000	NA
2B	184,000	8,000	19,000	211,000	NA
3A	797,000	489,000	129,000	1,415,000	288
3B(1)	708,000	496,000	121,000	1,325,000	270
3B(2)	2,333,000	496,000	283,000	3,112,000	634
3C	733,000	429,000	116,000	1,278,000	260
3D(1)	291,000	436,000	73,000	800,000	163
3D(2)	1,915,000	436,000	235,000	2,586,000	527
4A	1,130,000	791,000	192,000	2,113,000	430
4B(1)	1,052,000	799,000	185,000	2,036,000	415
4B(2)	2,677,000	799,000	348,000	3,824,000	779
4C	1,490,000	1,041,000	253,000	2,784,000	567
4D(1)	1,106,000	1,049,000	216,000	2,371,000	483
4D(2)	2,731,000	1,049,000	378,000	4,158,000	847
5A	1,681,000	400,000	208,000	2,289,000	466
5B(1)	1,305,000	400,000	171,000	1,876,000	382
5B(2)	2,930,000	400,000	333,000	3,663,000	746
6	923,000	0	92,000	1,015,000	207

Note: Costs are based on cleanup to Residential, 1x10-6 level
NA – Not Applicable (total cost is independent of soil volume)

Source: Arthur D. Little, Inc.

Table 4-7: Comparison of Costs for Different Risk-Based Cleanup Levels

Alternative	Residential, 1 x 10-6 Capital ($000)	Residential, 1 x 10-6 O&M ($000)	Residential, 1 x 10-6 Design/ Planning ($000)	Residential, 1 x 10-6 Total ($000)	Light Industrial, 1 x 10-6 & 1 x 10-5 Capital ($000)	Light Industrial, 1 x 10-6 & 1 x 10-5 O&M ($000)	Light Industrial, 1 x 10-6 & 1 x 10-5 Design/ Planning ($000)	Light Industrial, 1 x 10-6 & 1 x 10-5 Total ($000)
1	0	0	0	**0**	0	0	0	**0**
2A	113	8	11	**132**	74	8	8	**90**
2B	184	8	19	**211**	108	8	12	**128**
3A	797	489	129	**1415**	670	454	112	**1236**
3B(1)	708	496	121	**1325**	624	462	109	**1195**
3B(2)	2333	496	283	**3112**	2249	462	271	**2982**
3C	733	429	116	**1278**	416	258	67	**741**
3D(1)	291	436	73	**800**	189	266	46	**501**
3D(2)	1915	436	235	**2586**	1814	266	208	**2288**
4A	1130	791	192	**2113**	951	762	171	**1884**
4B(1)	1052	799	185	**2036**	913	770	168	**1851**
4B(2)	2677	799	348	**3824**	2538	770	331	**3639**
4C	1490	1041	253	**2784**	924	895	182	**2001**
4D(1)	1106	1049	216	**2371**	738	903	164	**1805**
4D(2)	2731	1049	378	**4158**	2362	903	327	**3592**
5A	1681	400	208	**2289**	1364	229	159	**1752**
5B(1)	1305	400	171	**1876**	1194	229	142	**1565**
5B(2)	2930	400	333	**3663**	2819	229	305	**3353**
6	923	0	92	**1015**	479	0	48	**527**

Source: Arthur D. Little, Inc.

Table 4-8: Areas and Volumes of Contaminated Sites Selected for Remediation

Site	Area (sq ft)	Volume (cu yd)
22	40000	1500
36	1500	170
Total	41500	1670
Total *	**42000**	**1700**

*Totals rounded to two significant figures

Note: Areas and volumes include uncertainty factor of 1.25

Source: Arthur D. Little, Inc.

Table 4-9: Comparison of Costs for Different Cleanup Levels at Sites 22 and 36

Alternative	Capital ($000)	O&M ($000)	Design/ Planning ($000)	Total ($000)
1	0	0	0	0
2A	51	8	6	65
2B	81	8	9	98
3A	632	443	108	1183
3B(1)	600	451	105	1156
3B(2)	2230	451	268	2949
3C	315	202	52	569
3D(1)	160	210	37	407
3D(2)	1800	210	201	2211
4	336	0	34	370

Notes:

- The above costs address the remediation of 1700 cubic yards of contaminated soil in an affected area of 42,000 square feet.
- Only metal-contaminated soil will be treated at these sites. The alternatives above are those evaluated in the FS that are applicable to metal-contaminated soil.

Source: Arthur D. Little, Inc.

5.0 References

1. Dames & Moore. *Final Enhanced Preliminary Assessment for Umatilla Depot Activity. Volumes 1 and 2.* Prepared for the U.S. Army Toxic and Hazardous Materials Agency. Contract No. DAAA15-88-D0008, Delivery Order No. 3. April 1990.

2. Dames & Moore. *Draft Final Remedial Investigation Report for the Umatilla Depot Activity Hermiston, Oregon.* Volumes 1 through 6. Prepared for the U.S. Army Toxic and Hazardous Materials Agency. Contract No. DAAA15-88-D-0008, Delivery Order No. 3. June 1992.

3. Environmental Protection Agency. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA.* EPA/540/G-89/004. October 1988.

4. Dames & Moore. *Draft Final Human Health Baseline Risk Assessment Umatilla Depot Activity Hermiston, Oregon.* Prepared for the U.S. Army Toxic and Hazardous Materials Agency. Contract No. DAAA15-88-D-0008, Delivery Order No. 3. June 1992.

5. Walker, George W. *Geologic Map of Oregon East of the 121st Meridian*, Misecellaneous Investigations Series Map I-902, scale: 1/500,000, 2 sheets, U.S. Geological Survey. 1977.

6. Hogenson, G.M. *Geology and Ground Water of the Umatilla River Basin, Oregon,* Water-Supply Paper 1620, U.S. Geological Survey. 1964.

7. Farooqui, Saleem M., Russell C. Bunker, Richard E. Thoms, and Daniel C. Clayton. *Post-Columbia River Basalt Group Stratigraphy and Map Compilation of the Columbia Plateau, Oregon.* Open-File Report 0-81-10, Oregon Department of Geology and Mineral Industries. 1981.

8. Dames & Moore. *Draft Intermediate and Alluvial Well Installation Report Site 4, Explosive Washout Lagoons Supplementary Remedial Investigation Report for the Umatilla Depot Activity Hermiston, Oregon.* Prepared for the U.S. Army Environmental Center. Contract No. DAAA15-90-D-00015, Delivery Order No. 10. March 1993.

9. U.S. Army Corps of Engineers. *Existing Water Well Study.* Walla Walla District, Engineer Support for Umatilla Depot Activity, Hermiston, Oregon. July 1987.

10. U.S. Department of Energy (DOE). *Environmental Assessment, Reference Repository Location, Hanford Site, Washington.* Office of Civilian Radioactive Waste Management, Washington, D.C. 1986

11. Miller, Donn W. *An Evaluation of Artificial Recharge to the Alluvial Ground Water Reservoir Near Ordnance, Oregon, for the Period 1977-1984*, Open File Report, Oregon Water Resources Department, 1985.

12. Geraghty, James, J., David W. Miller, Frits Van der Leeden, and Fred L. Troise. *Water Atlas of the United States*, Water Information Center. 1973.

13. OWRD. *Umatilla Basin Report*. 1988.

14. Bauer, H.H., and J.J. Vaccaro. *Estimates of Groundwater Recharge to the Columbia Plateau Regional Aquifer System, Washington, Oregon, and Idaho, for Predevelopment and Current Land-Use Conditions*. U.S. Geological Survey Water Resources Investigations, Report 88-4108. 1990.

15. Gale Research Company, *Climates of the States*, 3rd edition, 2 vols. 1985.

16. Roy F. Weston, Inc. *Umatilla Army Depot Activity Remedial Investigation*. Draft Final Report to U.S. Army Toxic and Hazardous Materials Agency. Report No. CETHA-IR-CR-89038. March 1989.

17. Umatilla Depot Activity Feasibility Study Scoping Meeting. Portland, Oregon. June 4, 1992.

18. Dames & Moore. *Draft Ecological Assessment (EA) Report, Remedial Investigation/Feasibility Study (RI/FS) of the Umatilla Depot Activity, Hermiston, Oregon*. Prepared for the U.S. Army Toxic and Hazardous Materials Agency, Contract No. DAAA15-88-D-0008, Delivery Order No. 3. June 1992.

19. Oregon Department of Environmental Quality. *Environmental Cleanup Manual*. October 1992.

20. Oak Ridge National Laboratory. *Assessment of Applicable or Relevant and Appropriate Requirements (ARARs) for Umatilla Depot Activity, Explosive Washout Lagoons, Oregon*. Prepared for the U.S. Army Toxic and Hazardous Materials Agency. May 1991.

21. Arthur D. Little, Inc. *Testing to Determine Relationship Between Explosive Contaminated Sludge Components and Reactivity*. Prepared for the U.S. Army Toxic and Hazardous Materials Agency. Contract DAAK11-85-D-0008. Report No. AMXTH-TE-CR-89096. January 1987.

5.0 References

22. U.S. Army Corps of Engineers, Seattle District. *Feasibility Study for the Deactivation Furnace (Site 1) Soils Operable Unit, Umatilla Army Depot Activity (UMDA), Hermiston, Oregon.* August 1992.

23. Montemagno, C.D., and R.L. Irvine. *Feasibility of Biodegrading TNT-Contaminated Soils in a Slurry Reactor.* Prepared for USATHAMA. Report No. CETHA-TE-90062. June 1990.

24. Roy F. Weston, Inc., *Windrow Composting Demonstration on Explosives-Contaminated Soils at Umatilla Depot Activity.* Prepublication copy of report prepared for USATHAMA. Report No. CETHA-TS-CR-93043. March 1993.

25. Oak Ridge National Laboratory. *Characterization of Explosives Process Decomposition Due to Composting.* Phase II Final Report. ORNL/TM-12029. November 1991.

26. USATHAMA. Personal communication between Kevin Keehan, USATHAMA and Janet Mahannah, Arthur D. Little, Inc. December 1992.

27. Lurgi. DECONTERRA® Soil Washing Process, Product Literature. 1992.

28. PTI Environmental Services. *Technical Memorandum, Soil Washing for Remediation of Lead-Contaminated Soils.* Prepared for the U.S.EPA Region 10. 1993.

29. Atlantic Research Corporation. *Engineering and Development Support of General Decon Technology for the U.S. Army's Installation Restoration Program.* Prepared for USATHAMA. Contract No. DAAK 11-80-C0027. 1982.

30. Environmental Protection Agency. Abstracts. Superfund Treatability Clearinghouse. EPA/540/2-89/001. August 1989.

31. Environmental Protection Agency. Engineering Bulletin - Soil Washing. 1991.

32. Roy F. Weston, Inc. *Heavy Metal Contaminated Soil Treatment: Conceptual Development.* Interim Report prepared for USATHAMA. Report No. AMXTH-TE-CR-86101.

33. Arthur D. Little, Inc. *An Evaluation of Three Leading Innovative Technologies for Potential Application to Basin F Materials at Rocky Mountain Arsenal.* Prepared for USATHAMA. Contract No. DAAK11-85-D-0008. April 1988.

34. Roy F. Weston, Inc. *Incineration Test of Explosives Contaminated Soils at Savanna Army Depot Activity, Savanna, Illinois.* Prepared for USATHAMA. Report No. DRXTH-TE-CR-84277. April 1984.

35. Roy F. Weston, Inc. *Economic Evaluation of Alternative Incineration Options for Explosives Contaminated Soils.* Prepared for USATHAMA. Contract No. DAAK11-82-C-0017. October 1984.

36. U.S. Army Toxic and Hazardous Materials Agency. *Louisiana Army Ammunition Plant-Area P Leaching Pits Closure and Post-Closure Plan.* August 1985.

37. Roy F. Weston, Inc. *Installation Restoration General Environmental Technology Development - Field Demonstration of Incinerator Feed System for Explosives Contaminated Soils.* Prepared for USATHAMA. Report No. AMXTH-TE-CR-86091. January 1987.

38. Environmental Protection Agency. *Superfund Engineering Issue: Issues Affecting the Aplicability and Success of Remedial/Removal Incineration Projects.* Office of Solid Waste and Emergency Response. EPA/540/2-91/004. February 1991.

39. Environmental Protection Agency. *Handbook for Stabilization/Solidification of Hazardous Wastes.* EPA/540/2-86/001. June 1986.

40. Environmental Protection Agency. *Stabilization/Solidification of CERCLA and RCRA Wastes: Physical Tests, Chemical Testing Procedures, Technology Screening, and Field Activities.* EPA/625/6-89/022. May 1989.

41. Funderburk & Associates. Personal communication between Ray Funderburk, Funderburk & Associates and Joyce O'Donnell, Arthur D. Little, Inc. December 1992.

42. Oregon Department of Environmental Quality (ODEQ), Letter from William H. Dana, ODEQ to Mark Daugherty, UMDA. June 22, 1993

43. USAEC Memorandum from Dr. Charles Lechner, USAEC, to Armand Balasco, Arthur D. Little, Inc. August 4, 1993.

Appendix A: Environmental Fate and Transport Properties

Appendix A

Environmental Fate and Transport Properties

Potential human and environmental exposure to each of the contaminants of concern is influenced by physical/chemical properties and the environmental fate and transport properties of each contaminant. Summaries of the important physical/chemical and environmental fate parameters for the organic and inorganic contaminants of concern at at UMDA are presented in Tables A-1 and A-2 respectively. Fate and transport profiles for each of the contaminants of concern are presented in Appendix C of the RA.

Several of the parameters listed in Tables A-1 and A-2 are used to calculate estimated values for other parameters used in the exposure assessment of the RA. For example, molecular weight and the octanol-water partition coefficient (K_{ow}) were used to calculate the chemical-specific dermal permeability constant (K_p); K_{ow}s were used to calculate plant and animal uptake factors; and Henry's Law constants were used to estimate transfer efficiencies. Other parameters listed in Tables A-1 and A-2 (e.g., solubility, vapor pressure, diffusion coefficient, organic carbon partition coefficient, and physical state) were not used for risk and hazard calculations, but were useful in predicting potential relevant future exposure pathways and helping to link sources with currently contaminated media.

The source of this summary is Section 4.0 of the RA as supplemented by Appendix C of the RA.

Table A-1: Important Physical and Chemical Pr[operties of] Contaminants of Concern

	CAS REG. NO.	CHEMICAL FORMULA	USATHAMA ABBR.	MOLECULAR WEIGHT (amu)	COLOR	FREEZING/ MELTING PT. (C)	BOILING POINT (C)	PHYSICAL STATE (at 20 C)	SOLID/ LIQUID DENSITY at 20 C (g/cm3)	R P
VOA										
Benzene	71–43–2	C6H6	C6H6	78.11	Colorless to light yellow(b1)	5.5(j1)	80.1(j1)	liquid(k1)	0.8765(o1)	–1
Tetrachloroethylene	127–18–4	C2Cl4	TCLEE	165.83	Colorless(k1)	–22.4(k1)	121.2(k1)	liquid(k1)	1.625(k1)	
1,1,1–Trichloroethane	71–55–6	CH3CCL3	111TCE	133.42	Colorless(k1)	–33(w3)	74(w3)	liquid(k1)	1.325(w3)	
Trichloroethylene	79–01–6	C2HCl3	TRCLE	131.39	Colorless(g2)	–87.1(d4)	87.2(v3)	liquid(k1)	1.462(v3)	3
Xylenes										
o–Xylene	95–47–6	C8H10	12DMB	106.16	Colorless(k1)	–25.2(w3)	144.4(w3)	liquid(k1)	0.8802(w3) at 25 C	3
m–Xylene	108–38–3	C8H10	13DMB	106.16	Colorless(k1)	–47.9(w3)	139.1(w3)	liquid(k1)	0.86417(w3) at 25 C	2
p–Xylene	106–42–3	C8H10	14DMB	106.16	Colorless(k1)	13.3(w3)	138.7(w3)	liquid(k1)	0.86105(w3) at 25 C	2
SVOA										
2–Methylnaphthalene	91–57–6	C11H10	2MNAP	142.21	•	34.58(a1)	241.1(a1)	solid(b1)	1.0058(c1)	9
Anthracene	120–12–7	C14H10	ANTRC	178.23	Colorless crystals, violet fluorescence(a1)	216(r1)	339.9(a1)	solid(a1)	1.134@	1
Benzo(A)anthracene	56–55–3	C18H12	BAANTR	228.29	Yellow–blue(u1)	162(u1)	400(a1)	solid(w1)	1.274(w1)	
Benzo(B)fluoranthene	205–99–2	C20H12	BBFANT	252.3	Colorless(x1)	168.3(x1)	•	solid(u1)	1.174@	
Benzo(K)fluoranthene	207–08–9	C20H12	BKFANT	252.3	Pale yellow(x1)	215.7(x1)	480(x1)	solid(w1)	1.174@	
Bis(2–ethylhexyl)phthalate	117–81–7	C24H38O4	B2EHP	390.62	Colorless(b2)	–50(c2)	385(b1)	liquid(d2)	0.9861(d2)	2
Chrysene	218–01–9	C18H12	CHRY	228.3	Colorless w/red and blue fluorescence(i2)	255–256(i2)	448(i2)	rhombic plates(i2)	1.274(i2)	
Di–n–butyl phthalate	84–74–2	C16H22O4	DNBP	278.35	Colorless(b1)	–35(b1)	340(c1)	oily liquid(b1)	1.047(c1)	1
Dibenzofuran	132–64–9	C12H8O	DBFU	168.19	White(o3)	86–87(u1)	287(u1)	solid(o2)	1.30@	
Fluoranthene	206–44–0	C16H10	FANT	202.26	Colorless(a1)	111(q2)	367(a1)	solid(a1)	1.165@	
N–nitrosodiphenylamine	86–30–6	C12H10N2O	NNDPA	198.24	Yellow to green(k1)(d2)	66.5(r2)	268.17(s2)	crystals(k1)	1.23(r2)	6
Naphthalene	91–20–3	C10H8	NAP	128.19	White(b1)	80.55(q2)	218(c1)	solid(b1)	1.145(c1)	8
Phenanthrene	58–01–8	C14H10	PHANTR	178.23	Colorless(b1)	101(t2)	339(a1)	solid(a1)	1.134@	1
Pyrene	129–00–00	C16H10	PYR	202.3	Pale yellow or slight blue(x1)	156(k2)	404(k2)	solid(w1)	1.271(w1)	
PESTICIDES/PCBs										
DDD	72–54–8	C14H10CL4	DDD	320.05	Colorless(k1)	109–110(w1)	193(w1)	crystals(k1)	1.813@	
DDE	75–55–9	C14H8Cl4	DDE	318.02	White(r2)	88.4(r2)	•	crystalline(r2)	1.492@	
DDT	50–29–3	C14H9Cl5	DDT	354.5	Colorless to slightly off–white(e3)	108.5(r2)	260(r2)	crystals or powder(e3)	1.59G@	7
Polychlorinated Biphenols PCB 1260	11096–82–5	C12H5Cl5(12%) C12H4Cl6(38%) C12H3Cl7(41%) C12H2Cl8(8%)	PCB260	375.7	Colorless(k1)	•	340–375(i3)	liquid(k1)	1.873–1.888@	
Chlordane	57–74–9	C10H6Cl18	CLDAN	409.8	Brown(w2)	cis:107–108.8; trans:103–105(t2)	175 at 2mmHg(k1)	liquid(k2)	1.59–1.63 at 25 C(k2)	
Dieldrin	60–57–1	C12H8Cl6O	DLDRN	380.93	Buff to light tan(j2)	175–176(j2)	••	solid(j2)	1.7@	
Endrin	72–20–8	C12H8Cl6O	ENDRN	380.90	White(w1)	235(s1)	•	solid(w1)	1.7(p2)	
EXPLOSIVES										
1,3,5–Trinitrobenzene	99–35–4	C6H3N3O6	135TNB	213.12	Yellow(a1)	122(q3)	•	solid(a1)	1.63(r3)	
1,3–Dinitrobenzene	99–65–0	C6H4N2O4	13DNB	168.11	Yellowish(b1)	89.8(b1)	300–302 at 770 mm Hg(b1)	solid(b1)	1.575(k3)	
2,4,6–Trinitrotoluene	118–96–7	C7H5N3O6	246TNT	227.13	Colorless(b1)	80.75(b4)	240(b1) (explodes)	solid(b1)	1.65(b4)	
2,4–Dinitrotoluene	121–14–2	CH3C6H3(NO2)2	24DNT	182.15	Yellow(b1)	72(n3)	300(b1)	solid(b1)	1.521(n3)	2
2,6–Dinitrotoluene	606–20–2	CH3C6H3(NO2)2	26DNT	182.14	Yellow(m2)	66(n3)	285(m3)	solid(b1)	1.538(n3)	
HMX	2691–41–0	C4H8N8O8	HMX	296.2	Colorless(k4)	286(n3)	•	solid(n3)	1.90(n3)	
Nitrobenzene	98–95–3	C6H5NO2	NB	123.11	Yellow(b1)	5.6(t2)	210.8(c1)	liquid(c1)	1.20(b1) at 25 C	8
RDX	121–82–4	C3H6N6O6	RDX	222.15	White(a1)	205(t3)	•	solid(a1)	1.83(n3)	
Tetryl	479–45–8	C7H5N5O8	Tetryl	287.17	Yellow(c1)	129.5(n3)	••	solid(c1)	1.73(n3)	

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:AL E :)	SOLID/ LIQUID DENSITY at 20 C (g/cm3)	FLASH POINT (C)	SOLUBILITY IN WATER (mg/L at 20 C)	VAPOR PRESSURE (mm Hg at 20 C)	HENRY'S LAW CONSTANT (atm-m3/ mole at 20 C)	OCTANOL-WATER PARTITION COEFFICIENT (Kow)	ORGANIC-CARBON PARTITION COEFFICIENT (Koc)(mL/g)	DIFFUSION COEFFICIENT IN WATER/AIR (cm2/s at 20 C)
	0.8765(o1)	-11 (k1)	1780 (b1)	76 (b1)	5.4E-03 (l1)	134.90 (m1)	65 (n1)	8.99E-06@/**
	1.625(k1)	**	150 (p1)	14 (p1)	2.27E-02 (l1)	1,380.38 (m1)	665 (q1)	7.59E-06@/**
	1.325(w3)	*	950(w3)	100(p1)	1.72E-02(h4)~	309(i4)	152(j4)	8.11E-06@/**
	1.462(v3)	32.2(f3)	1,100(u3)	58.7(v3)	8.92E-03(l1)	154.98(a2)	127(n1)	8.43E-06@/**
	0.8802(w3) at 25 C	31(w3)	0.3(p1)	7(p1)	5.19E-03(x3)~	1,318.26(m1)	129(g1)	7.19E-06@/**
	0.86417(w3) at 25 C	29(w3)	0.3(p1)	9(p1)	7.19E-03(y3)~	1,584.89(m1)	166(g1)	7.19E-06@/**
	0.86105(w3) at 25 C	27(w3)	0.3(p1)	9(p1)	7.60E-03(y3)~	1,412.54(m1)	260(z3)	7.19E-06@/**
	1.0058(c1)	97(d1)	24.6(e1);25.4(f1)§	*	*	7,244(i1)	8,511(g1);7,413(h1)	6.43E-06@/**
	1.134@	121(a1)	0.073(f1)§	1.95E-04(r1)	1.45E-03(s1)	28,183.83(r1)	18,621(g1); 25,704(t1)	5.66E-06@/**
	1.274(w1)	*	0.009-0.014(x1)	2.2E-08(w1)	1.0E-06(w1)	4.1E+05(s1)	2.0E+05(s1)	5.11E-06@/**
	1.174@	*	0.014(y1)	(E-11)-(E-06)(s1)	1.22E-05(s1)	1.1E+06(w1)	5.5E+05(s1)	4.78E-06@/**
	1.174@	*	5.5E-04(z1)§	5.0E-07(s1)	3.87E-05(s1)	6.91E+06(a2)	5.5E+05(s1)	4.78E-06@/**
	0.9861(d2)	215(e2)	0.3(f2)§	6.45E-06(f2)++	1.1E-05(f2)~	7.586E+04(g2)	100,000(h2)	3.32E-06@/**
	1.274(i2)	*	0.0015-0.0022(x1)	6.3E-09(y1)	1.05E-06(y1)	4.1E+05(y1)	2.0E+05(y1)	5.11E-06@/**
b1)	1.047(c1)	171(o2)	0.013(s1)	1.0E-05(s1)++	2.0E-07(s1)	3.98E+05(s1)	1.698E+05(s1)	4.22E-06@/**
	1.30@	*	10(t3)§	0.0044(g3)++	9.73E-05(w1)	1.32E+04(w1)	4,600-6,350(n2)	6.12E-6@/**
	1.165@	*	0.26(f1)§	0.01(a1)	6.5E-06(s1)	213,796.21(a2)	9,157@	5.39E-06@/**
l)	1.23(r2)	61(d1)	113(n1)§	6.3E-04(n1)++	1.4E-06(n1)~	1,348.96(m1)	650(n1)	5.13E-06@/**
	1.145(c1)	80(a1)	31.7(s1)(w1)	0.0492(s1)	4.6E-04(s1)	2,344(r1)	933.25(s1)	6.98E-06@/**
	1.134@	171(u2)	1.29(f1)§	6.8E-04(r1)	2.26E-04(s1)	28,340.32(r1)	5,248(g1);22,909(t1); 38,905(v2)	5.85E-06@/**
	1.271(w1)	*	0.125-0.165(x1)	2.5E-06(s1)++	5.1E-06(s1)	8.0E+04(s1)	3.8E+04(s1)	5.61E-06@/**
l)	1.813@	**	0.16 at 24 C(b1)	(1.3-2.5)E-09 at 30 C(t2)	3.1E-05(t2)~	363,078(c3)	240,000(c3)	4.49E-06@/**
(r2)	1.492@	*	0.040(b1)	(6.2-6.6)E-06(d3)	1.9E-04(d3)~	489,778(d3)	257,000(d3)	4.55E-06@/**
l)	1.599@	72.2-77.2(f3)	0.0031-0.0034(b1)§	1.5E-07(e3)	5.13E-04(b3)	2.29E+06(h3)	302,000(c3)	4.32E-06@/**
	1.873-1.888@	*	0.0027(t2)	4E-05(t2)++	3.4E-04(j3)	1.2E+06-2.0E+09(n1)~	E+05-E+09(q1)	4.46E-06@/**
	1.59-1.63 at 25 C(k2)	56(a4)	0.056(x2); 1.850(y2)§	1.0E-05(z2)	4.8E-05(a3)~	346,736.85(b3)	3,090-43,652#	3.13E-06@/**
	1.7@	**	0.186(j2)	3.1E-06(k2)	2.0E-07(l2)	2.51E+04	1.1E+04@	4.33E-06@/**
	1.7(p2)	27(w1)	0.25(s1)§	2.7E-07(s1)++	4.0E-07(s1)	2.18E+05(s1)	1,698(s1)	4.33E-06@/**
	1.63(r3)	*	385(r3)§	3.03E-06(s3)++	2.21E-09(n3)~	15.14(n3)	19.95(p3)	7.2E-06 at 25 C(g4)/**
	1.575(k3)	*	533(l3)§	1.31E-04(m3)++	5.44E-08(n3)~	30.9(n3)	36.31(p3)	7.94E-06 at 25 C(g4)/**
	1.65(b4)	*	123(c4)	8.02E-06(f4)	1.1E-08(n3)~	100(n3)	524.8(n3)	6.71E-06(n3)/**
	1.521(n3)	207(w1)	280(n3)§	5.1E-03(s1)	1.86E-07(n3)~	95.50(n3)	251.20(n3); 44.67(s1)	7.31E-06(n3)/**
	1.538(n3)	*	180(s1)	0.018(s1)	4.86E-07(n3)~	77.62(n3)	77.62(n3);48.98(s1)	7.31E-06(n3)/**
	1.90(n3)	*	5.0(v1)	3.33E-14(n3)++	2.60E-15(n3)~	1.82(n3)	3.47(n3)	6.02E-06(n3)/**
	1.20(b1) at 25 C	87.7(o2)	1,900(b1)	0.15(b1)	1.53E-05(t2)~	70.8(t2)	36.31(s1)	7.72E-06@/**
	1.83(n3)	*	60(t3)§	4.03E-09(s3)(r3)++	1.96E-11(n3)~	7.41(n3)	100(e4)	7.15E-06(n3)/**
	1.73(n3)	187(c1)	80(n3)§	5.69E-09(n3)++	2.69E-11(n3)~	44.67(n3)	48.98(n3)	5.99E-06(n3)/**

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References for Table A-1

a1=Sax and Lewis, 1989
b1=Verschueren, 1983
c1=Weast et al., 1985
d1=Aldrich Chemical Co., 1988
e1=Eganhouse and Calder, 1976
f1=Mackay and Shiu, 1977
g1=Abdul et al., 1987
h1=Hodson and Williams, 1988
i1=Yoshida et al., 1983
j1=Weast, 1977
k1=Hawley, 1981
l1=Mackay and Shiu, 1981
m1=Leo, 1983
n1=Arthur D. Little, Inc., 1985
o1=Weast, 1984
p1=Mackison et al., 1981
q1=Means et al., 1982
r1=Radding et al., 1976
s1=Mabey et al., 1982
t1=Karickhoff et al., 1979
u1=Weast et al., 1988
v1=Glover and Hoffsommer, 1973
w1=HSDB, 1988
x1=IARC, 1983
y1=USEPA, 1982
z1=Walton, 1985

a2=Leo et al., 1971
b2=CHRIS, 1978
c2=Patty, 1963
d2=IARC, 1982
e2=NFPA, 1978
f2=Howard, 1989
g2=HSDB, 1987
h2=Neely and Blau, 1985
i2=CRC, 1987
j2=Worthing and Walker, 1983
k2=Windholz, 1983
l2=Thomas, 1982
m2=USPHS, 1989
n2=Karickhoff, 1985
o2=Sax and Lewis, 1987
p2=USEPA, 1980
q2=Cleland and Kingsbury, 1977
r2=TDB, 1984
s2=USEPA, 1987
t2=Callahan et al., 1979
u2=NFPA, 1984
v2=Socha and Carpenter, 1987
w2=Hartley and Kidd, 1983
x2=Sanborn et al., 1976
y2=Weil et al., 1974
z2=Martin, 1972

a3=Suntio et al., 1988
b3=USEPA, 1986
c3=Kadeg et al., 1986
d3=Arthur D. Little, Inc., 1987
e3=Clayton and Clayton, 1981
f3=Weiss, 1986
g3=Chao et al., 1983
h3=Chiou et al., 1982
i3=Sittig, 1981
j3=Burkhard et al., 1985
k3=Weast, 1979
l3=Leiga and Sarmousakis, 1966
m3=Maksimov, 1963
n3=Burrows et al., 1989
o3=Sax, 1979
p3=Lyman and Loreti, 1987
q3=Clark and Hartman, 1941
r3=Urbanski, 1985
s3=Cundall et al., 1981
t3=Banerjee et al., 1980
u3=Pearson and McConnell, 1975
v3=Reid et al., 1977
w3=Grayson and Eckroth, 1978
x3=Sanemasa et al., 1982
y3=SRC, 1988
z3=Vowles and Mantoura, 1987

a4=OHM-TADS, 1988
b4=Linder, 1980
c4=Spanggord et al., 1980a
d4=McNeil, 1979
e4=Rosenblatt, 1986
f4=Pella, 1977
g4=Lyman et al., 1982
h4=Gossett, 1987
i4=Hansch and Leo, 1985
j4=Mabey et al., 1981
k4=USEPA, 1988

@=Dames & Moore calculation as per Section C.1.2
*=Value was not found during profile preparation
**=Not relevant at normal environmental conditions
§=Solubility in Water (mg/L at 25 C)
++=Vapor Pressure (mm Hg at 25 C)
~=Henry's Law Constant (atm-m3/mole at 25 C)
#=Estimated for pure chlordane by USPHS, 1988, using Equations 4-5 and 4-8 in Lyman et al., 1982

Full references are presented in Appendix C.3.

Table A-2: Important Physical and Chemical Properties of the Contaminants of Concern (Continued)

	CAS REG. NO.	CHEMICAL FORMULA/ USATHAMA ABBR.	MOLECULAR WEIGHT (amu)	COLOR	PHYSICAL STATE (at 20 C)	VALENCE STATES	MELTING POINT (C)	BOILING POINT (C)	DENSITY at 20 C (g/cm3)	VAPOR PRESSURE (mm Hg at 20 C)	
INORGANICS											
Mercury §	7439-97-6(b)	Hg/HG(a)	200.59(b)	Silvery-white(b)	heavy, mobile, liquid metal; solid is malleable, may be cut by a knife(b)	+1,+2(g)	-38.87(b)	352.72(b)	13.534 at 25 C(b)++	2E-03 at 25 C(b)++	5.
Nickel §	7440-02-0(b)	Ni/NI(a)	58.7(b)	Silvery(o)	solid(q)	+2; seldom +1,+3,+4(g)	1,455(q)	2,920(q)	8.90(q)	1 at 1,810 (c)++	in
Potassium	7440-09-7(c)	K/K(a)	39.0983(g)	Silvery-white metal(c)	solid(c)	+1(g)	63.2(g)	765.5(g)	0.362(c)	•	re wa
Selenium §	7782-49-2(b)	Se/SE(a)	78.96(b)	Metallic gray to black(b)	solid(b)	-2,+4,+6(d)	144; 217; 221(b)	685(b)	4.81(b)	1 at 356 C(b)++	in
Silver §	7440-22-4(b)	Ag/AG(a)	107.868(j)	Lustrous, white(j)	solid(r)	+1,+2(o)	961.93(j)	2,212 at 760mm Hg (j)	10.50(j)	liquid=100 at 1,865 C(j)++	ins
Sodium	7440-23-5(c)	Na/NA(a)	22.9898(c)	Light-silvery white metal(o)	soft solid(o)	+1(o)	97.82(o)	881.4(o)	0.971(c)	1.2 at 400 C(c)++	re wa
Thallium §	7440-28-0(b)	Tl/TL(a)	204.38(b)	Bluish-white(b)	solid(b)	+1,+3(g)	303.5(b)	1,457 +/-10(b)	11.85(b)	1 at 825 C(c)++	ins
Vanadium §	7440-62-2(r)	V/V(a)	50.942(r)	Silver-gray(r)	solid(r)	+2,+3,+4, +5(o)	1,890+/-10; 1,917(r,o)	3,880(r)	6.11 at 18.7 C(o)++	•	ins
Zinc §	7440-66-6(b)	Zn/ZN(a)	65.38(b)	Bluish-white, lustrous metal(o)	solid(b)	+2(o)	419.5(o)	908(o)	7.14 at 25 C(b)++	1 at 487 C(b)++	ins
ANIONS											
Cyanide § (see ref. notes)	57-12-5(l)	CN/CYN(a)	26.02(CN)(l)	Colorless (HCN)(n)	liquid (HCN)(n)	-1(n)	-13.2 (HCN)(n)	25.7 (HCN)(n)	0.6884 (HCN)(b)	620(HCN)(w)++	mi (H
Nitrates	7697-37-2 (HNO3)(g)	NO3/NO3(a)	62.00(NO3)(d)	Bluish (NO3)(d)	gas (NO3)(d)	-1(NO3)(c)	-42 (HNO3)(d)	83 (HNO3)(d)	1.5027 at 25 C (HNO3)(d)++	•	sol (H

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sical and Chemical Properties of the Inorganic
of Concern (Continued)

'ING NT)	BOILING POINT (C)	DENSITY at 20 C (g/cm3)	VAPOR PRESSURE (mm Hg at 20 C)	SOLUBILITY IN WATER (mg/L at 20 C)	SOLVENTS	FLAMMABILITY
b)	352.72(b)	13.534 at 25 C(b)++	2E-03 at 25 C(b)++	5.6E-03 g/100cc(b)	0.24 +0.012 in benzene, 0.1 in isopropyl ether, 0.24 in cyclohexane, 0.13 in octane(p)	not flammable(g)
)	2,920(q)	8.90(q)	1 at 1,810 (c)++	insoluble(q)	insoluble(q)	powders may ignite spontaneously in air(c)
	765.5(g)	0.362(c)	•	reacts violently with water(g)	liquid ammonia, ethylene-diamine, aniline(x); reacts violently with alcohols (n-propanol through n-octanol, benzyl alcohol, cyclohexanol)(c)	highly flammable; violent explosion hazard(c)
7;	685(b)	4.31(b)	1 at 356 C(b)++	insoluble(b)	insoluble in alcohol, slightly soluble in ether(c)	
j)	2,212 at 760mm Hg (j)	10.50(j)	liquid=100 at 1,865 C(j)++	insoluble(o)	nitric acid, hot sulfuric acid and alkali cyanide solutions(e)	dust is flammable(c)
	881.4(o)	0.971(c)	1.2 at 400 C(c)++	reacts violently with water(c)	reacts exothermally with halogenated hydrocarbon(c); dissolves in mercury(o)	highly flammable; explosion danger when wet(c)
)	1,457 +/-10(b)	11.85(b)	1 at 825 C(c)++	insoluble(b)	nitric or sulphuric acid(b)	dust is flammable(c)
-10;))	3,880(r)	6.11 at 18.7 C(o)++	•	insoluble(o)	aqua regia, HNO3, H2SO4, and HF(d)	dust is flammable; can react violently(c)
	908(o)	7.14 at 25 C(b)++	1 at 487 C(b)++	insoluble(b)	acetic acid and alkali (b)	flammable; may ignite spontaneously in air when dry; explosive reaction with acids(c)
)	25.7 (HCN)(n)	0.6884 (HCN)(b)	620(HCN)(w)++	miscible (HCN)(n)	ethanol(HCN)(b)	flammable; possibly explosive(c)
d)	83 (HNO3)(d)	1.5027 at 25 C (HNO3)(d)++	•	soluble (HNO3)(d)	ether(NO3)(d)	flammable and/or explosive(NO3)(c)

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Table A-2: Important Physical and Chemical Proper[…] Contaminants of Concern

	CAS REG. NO.	CHEMICAL FORMULA/ USATHAMA ABBR.	MOLECULAR WEIGHT (amu)	COLOR	PHYSICAL STATE (at 20 C)	VALENCE STATES	MELTING POINT (C)	BOILING POINT (C)	DENSITY at 20 C (g/cm3)	P (mm
INORGANICS										
Aluminum §	7429-90-5(b)	Al/AL(a)	26.98(b)	Tin-white, with bluish tint(b)	solid, metals(b)	+3(e)	660(b)	2,327(b); 2,450(c)	2.70(b)	1 at
Antimony §	7440-36-8(b)	Sb/SB(a)	121.75(b)	Silvery white(b)	solid(b)	0,-3,+3,+5(f) 4(e)	630.5(b)	1,750(b); 1,325(l); 1,635(o)	6.688(l)	1 at
Arsenic §	7440-38-2(b)	As/AS(a)	74.92(b)	Silver gray(b)	solid(b)	+2,+3,+5(e); 0,-3(f)	817 (28 atm)(b)	613 (sublimes)(b)	5.727(b)	0(s) (sub
Barium §	7440-39-3(b)	Ba/BA(a)	137.3(b)	Silver-white(b)	malleable metal(e)	+2(b)	710(o); 725(b)	1,000(o); 1,640(b)	3.51(b)	10 at
Beryllium §	7440-41-7(b)	Be/BE(a)	9.012(b)	Steel gray(b)	solid; hexagonal structure(b)	+2(e)	1,287 to 1,292(b)	2,970(b)	1.846(b)	1 at
Cadmium §	7440-43-9(b)	Cd/CD(a)	112.41(b)	Silver-white(b)	solid(b)	+2(e)	321(b)	765(b)	8.65(b)	1 at
Calcium	7440-70-2(g)	Ca/CA(a)	40.08(e)	Silver-white(e)	solid (crystalline metal)(e)	+2(e)	850(g)	1,440(g)	1.54(g)	10
Chromium §	7440-47-3(b)	Cr/CR(a)	51.996(b)	Steel gray(b)	solid(b)	+2,+3,+6(e)	1,857(b)	2,672(e)	7.20 at 28 C(b)	1 at 1
Cobalt §	7440-48-4(b)	Co/CO(a)	58.93(b)	Silvery gray(b)	solid(b)	+2,+3(e); 1, 2, 3, rarely 4 and 5(g)	1,495(b)	2,870(b)	8.9(b)	1 at 1
Copper §	7440-50-8(b)	Cu/CU(a)	63.546(b)	Reddish(b)	solid(b)	+1,+2(e)	1,083.4(b)	2,567(b)	8.92(b)	1 at 10 at
Iron	7439-89-6(g)	Fe/FE(a)	55.847(f)	Silver(f)	solid(e)	+2,+3(e); seldom +1, +4,+6(g)	1,535(f)	2,750(f)	7.86(f)	
Lead §	7439-92-1(b)	Pb/PB(a)	207.2(b)	Bluish-gray(b)	solid(b)	+2,+4(g)	327.4(b)	1,770(g)	11.35(b)	1 at
Magnesium	7439-95-4(c)	Mg/MG(a)	24.31(c)	Silvery-white metal(c)	solid(c)	+2(g)	651(y)	1,100(c)	1.738(c)	1 at
Manganese §	7439-96-5(b)	Mn/MN(a)	54.94(o)	Silver(b)	solid(b)	+1,+2,+3, +4,+6,+7(g)	1,244(z)	1,962(z)	7.20(z)	1 at

(1)

and Chemical Properties of the Inorganic
›ncern

BOILING POINT (C)	DENSITY at 20 C (g/cm3)	VAPOR PRESSURE (mm Hg at 20 C)	SOLUBILITY IN WATER (mg/L at 20 C)	SOLVENTS	FLAMMABILITY
2,327(b); 2,450(c)	2.70(b)	1 at 1,284 C(c)++	insoluble(d)	soluble in alkali, HCl,H2SO4(f)	flammable solid; spontaneous combustion(c)
1,750(b); 1,325(t); 1,635(o)	6.688(t)	1 at 886 C(x)++	insoluble(b)	hot conc. H2SO4, aqua regia(f)	moderate fire and explosion hazard as dust or vapor(c)
613 sublimes)(b)	5.727(b)	0(s); 1 at 372 C (sublimes)(g)++	insoluble(f)	Soluble HNO3(f)	dust is flammable when exposed to flame or through reaction with oxidizers(c)
1,000(o); 1,640(b)	3.51(b)	10 at 1,049 C(v)++	decomposes (temp. unspecified)(v)	alchohol(b)	dust is flammable or explosive(e)
2,970(b)	1.846(b)	1 at 1,520 C(b)++	insoluble(i)	dilute acid and alkali(b)	forms explosive mixtures in air(h)
765(b)	8.65(b)	1 at 1,284 C(e)++	insoluble(c)	acids, esp. nitric and ammonium nitrate solutions (f)	combustible; flammable; sometimes explosive(c)
1,440(g)	1.54(g)	10 at 983(c)++	decomposes(f)	acids(e)	flammable; spontaneous combustion; moderately explosive(c,h)
2,672(e)	7.20 at 28 C(b)	1 at 1,616 C(b)++	insoluble(b)	insoluble(b)	ignites and is potentially explosive(c)
2,870(b)	8.9(b)	1 at 1,910 C(b)++	insoluble(b)	acids(b)	flammable; possibly explosive(c)
2,567(b)	8.92(b)	1 at 1,628 C(k); 10 at 1,870 C(b)++	insoluble(b)	nitric acid and hot conc. sulfuric acid(e); HCl, NH4OH(f)	flammable(e); possibly explosive(c)
2,750(f)	7.86(f)	•	insoluble(f)	acids(f)	powder is pyrophoric and potentially explosive(c)
1,770(g)	11.35(b)	1 at 980 C(b)++	insoluble(b)	HNO3,hot conc. H2SO4(d)	dust is flammable; moderately explosive(c)
1,100(c)	1.738(c)	1 at 621 C(c)++	reacts violently with water, moisture(c)	acids(e)	powder is flammable particularly in the presence of water; may explode or react violently(c)
1,962(z)	7.20(z)	1 at 1,292 C(u)	decomposes(b)	dissolves in dilute mineral acid(e)	dust or powder is flammable(e)

(2)

References for Table A-2

a=IRDMIS (May 30, 1990)	i=USEPA (1980)	r=Grayson (1983)	*=Value was not found during profile preparation
b=USPHS (see §)	j=Weast (1988)	s=USEPA (1981)	**=Not relevant at normal environmental conditions
c=Sax and Lewis (1989)	k=Callahan et al. (1979)	t=Herbot et al. (1985)	++=Value found for temperature other than 20 C
d=Weast (1989)	l=Arthur D. Little, Inc. (1987)	u=Kirk-Othmer (1967)	
e=Hawley (1981)	m=HSDB (1991)	v=USEPA (1984)	
f=Weast (1982)	n=Clayton and Clayton (1981)	w=Verschueren (1983)	
g=Budavari (1989)	o=Windholz (1983)	x=HSDB (1989)	
h=National Fire Protection Association (1986)	p=Spencer and Voight (1968)	y=Rose et al. (1979)	
	q=Weast (1986)	z=Cotton and Wilkinson (1962)	

§ = USPHS toxilogical profiles are available for each of the following inorganics:

Aluminum	October,1990	Cadmium	November,1987	Lead	February,1988	Silver	December,1990
Antimony	October,1990	Chromium	October,1987	Manganese	October,1990	Thallium	October,1990
Arsenic	November,1987	Cobalt	October,1990	Mercury	December,1989	Vanadium	October,1990
Barium	October,1990	Copper	December,1990	Nickel	October,1987	Zinc	December,1989
Beryllium	October,1987	Cyanide	January,1988	Selenium	December,1989		

Note re: cyanide:

Additional properties:

Odor Threshold in Air: 0.58 ppm (v/v)

Odor Threshold in Water: 0.17 ppm (w/v)

Henry's Law Constant: 1.22E-04 atm-m3/mole at 25 C(f1)++

Full references are presented in Appendix C.3.

Appendix B: Area and Volume Calculation Worksheet and Maps

Appendix B: Area and Volume Calculation Worksheet and Maps

SITE sample	DESCRIPTION OF CONTAMINATION AND AREA CALCULATION / VOLUME CALCULATION	VOLUME (cu yd)	RISK LEVEL AFFECTED
Site 22 Sample 22-5 & Sample 22-6	Rectangular area on both sides of a railroad spur in the western portion of the DRMO area. This area includes samples 22-5 and 22-6. Assume the contamination (metals) is confined to the surface and that a one-foot excavation will remove it. Further sampling during the remedial design phase will be necessary to confirm that a one-foot excavation will remove the contaminant. 230 ft wide times 140 ft long 32200 ft2 x 1 ft deep = 32200 ft3 = x1.25	1193 yd3 **1491** *	R(-6), LI
Site 25-I Sample 25-1& Sample 25-3	Samples 25-1 and 25-3 are at the ends of the former northwest pile of thallium ore located on the western side of the railroad line passing through the site. Assume the contamination (thallium) is confined to the surface and a one-foot excavation will remove it. Further sampling during the remedial design phase will be necessary to confirm that a one-foot excavation will remove the contaminant. 600 ft long (north/south) 50 ft wide (east/west) 30000 ft2 x 1 ft deep = 30000 ft3 = x1.25	1111 yd3 **1389**	R(-6)
Sample 25-6	This sample is located on the southern end of the former southeastern pile of thallium ore located on the eastern side of the railroad line passing through the site. Since only sample 25-6 showed exceedances for thallium in the former ore pile, assume only the souther quarter of the former pile is contaminated on the surface only and a one-foot excavation will remove it. Further sampling during the remedial design phase will be necessary to confirm that a one-foot excavation will remove the contaminant. 125 ft long (north/south) 50 ft wide (east/west) 6250 ft2 x 1 ft deep = 6250 ft3 = x1.25	231 yd3 **289**	R(-6)
Site 36	This site has a steep grade below Bldg. 493 where paint sludge was discharged in two areas into Coyote Coulee. With the steep grade, the discharges probably didn't penetrate the ground very deeply or spread laterally too far.		
Sample 36-1	Assume contamination is confined directly under the discharge pipe where sample 36-1 was obtained and extends three feet deep. Further sampling during the remedial design will be necessary to confirm the assumption of contamination to only three feet and to determine further contamination occurred down gradient from the site. 60 ft long (east/west) times 10 ft wide (north/south) 600 ft2 x 3 ft deep = 1800 ft3 = x1.25	67 yd3 **83**	R(-6), LI
Sample 36-4	This sample was also at a point discharge into similar topography 60 ft long (east/west) times 10 ft wide (north/south) 600 ft2 x 3 ft deep = 1800 ft3 = x1.25	67 yd3 **83**	R(-6), LI

Appendix B: Area and Volume Calculation Worksheet and Maps

SITE sample	DESCRIPTION OF CONTAMINATION AND AREA CALCULATION / VOLUME CALCULATION	VOLUME (cu yd)	RISK LEVEL AFFECTED
Site 37	This site was the paint sludge discharge area for Bldg. 131 into an area near samples 37-2 and 37-4		
	60 ft long (east/west) times		
Samples 37-2	25 ft wide (north/south)		
and 37-4	2 $\boxed{X}$ 1500 ft2 x 3 ft deep = 9000 ft3 =	333 yd3	R(-6), LI
	x1.25	**417**	
Site 47	Sample 47-3 was a surface sample collected in center of a dry pit that once was a water infiltration pit. Since the surface was contaminated with metals and pesticides, one may conservatively assume that up to 10 feet of soil may be contaminated beneath the pit.		
Sample 47-3	Pit diameter = 30 ft		
	Pit area = π x (15)2 ft2 = 707 ft2		
	707 ft2 x 10 ft deep = 7070 ft3 =	262 yd3	R(-6), LI
	x1.25	**327**	
Sample 47-5	This sample was located in a trench leading towards the dry pit and soil samples show organic contaminants present to at least 3 feet. Assume the contamination can be removed by excavating to 6 feet.		
	100 ft long (north/south) times		
	10 ft wide (east/west)		
	1000 ft2 x 6 ft deep = 6000 ft3 =	222 yd3	R(-6)
	x1.25	**278**	
Site 48	This pipe discharge trench has contamination as shown in sample 48-2 which is located between samples 48-1 and 48-3 with acceptable levels of contamination. Assume contaminated area extends halfway between the contaminated sample and the "non-contaminated" samples and that contamination does not extend more than 3 feet deep.		
Sample 48-2	75 ft long (east/west) times		
	50 ft wide (north/south)		
	3750 ft2 x 3 ft deep = 11250 ft3 =	417 yd3	R(-6)
	x1.25	**521**	

* - Contingency Factor of 1.25 used

Source: Arthur D. Little, Inc.

Figure B-1: Site 22, Defense Re-Utilization Marketing Office Area

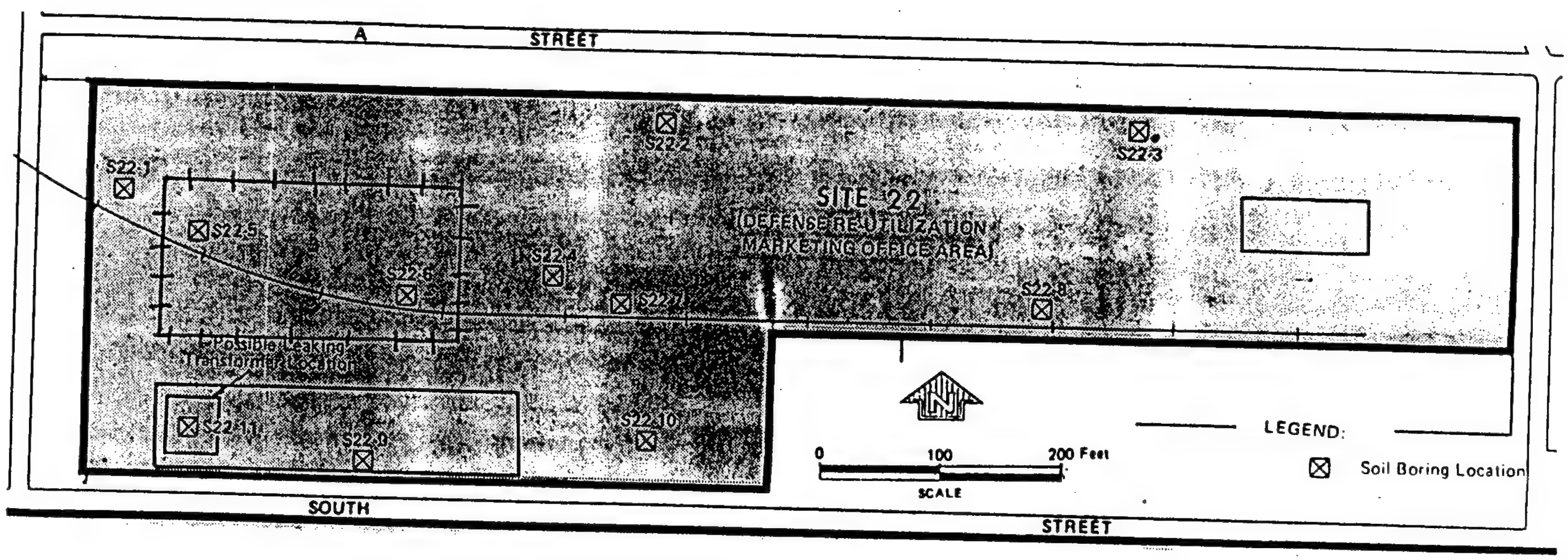


Figure B-2: Site 25I - Metal Ore Piles Location I

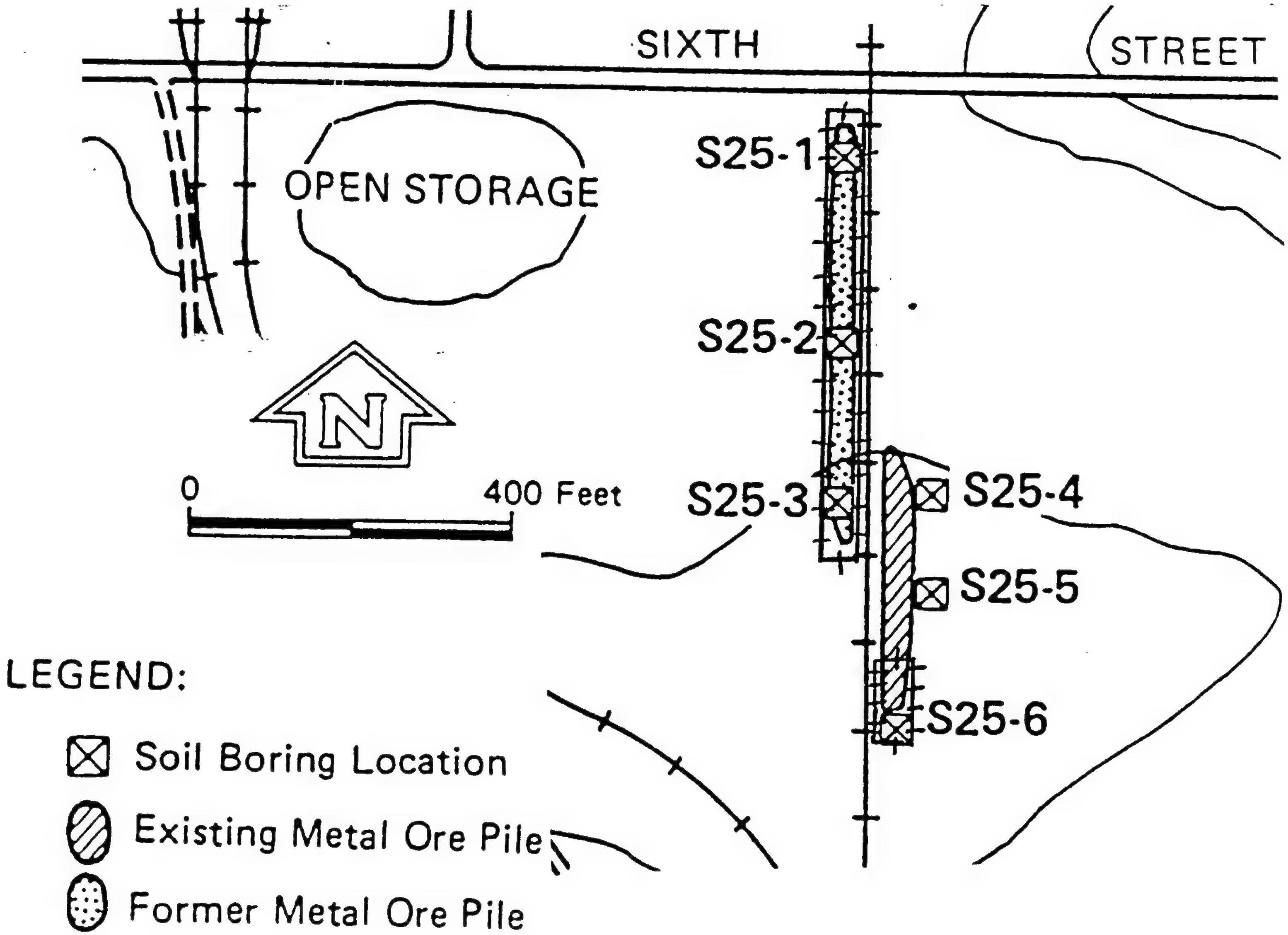


Figure B-3: Site 36, Building 493 Paint Sludge Discharge Area

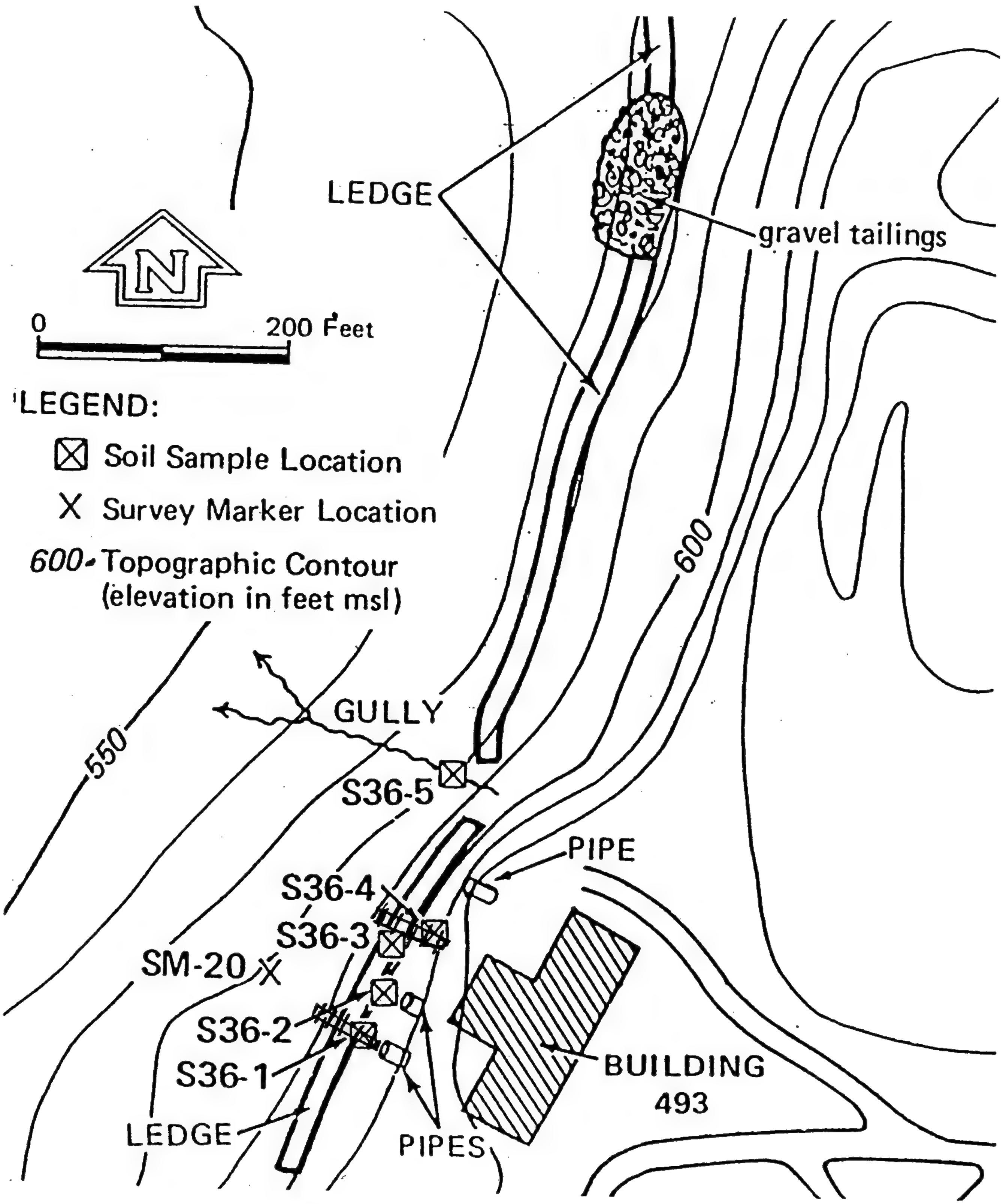


Figure B-4: Site 37, Building 131 Paint Sludge Discharge Area

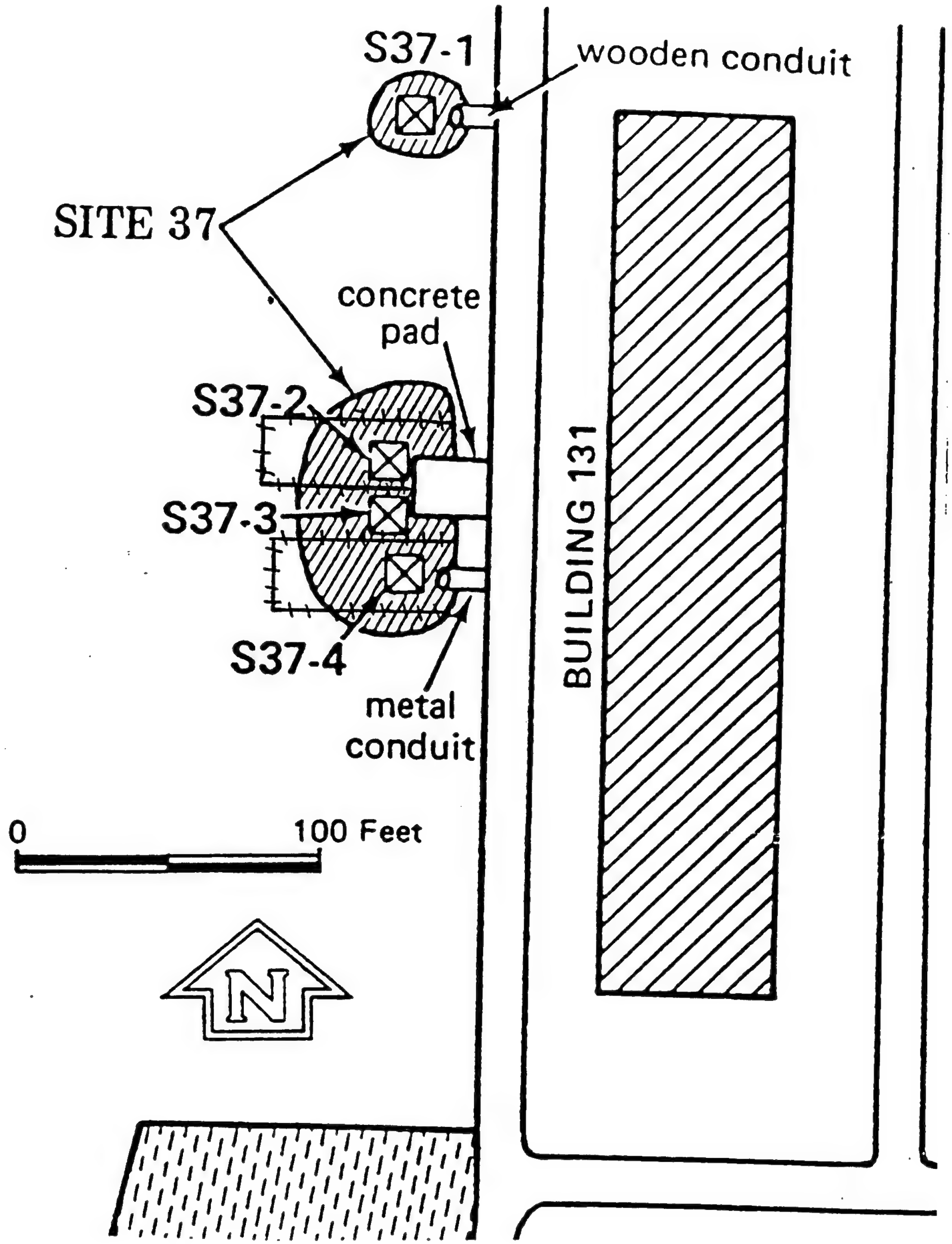


Figure B-5: Site 47, Boiler/Laundry Effluent Discharge Site

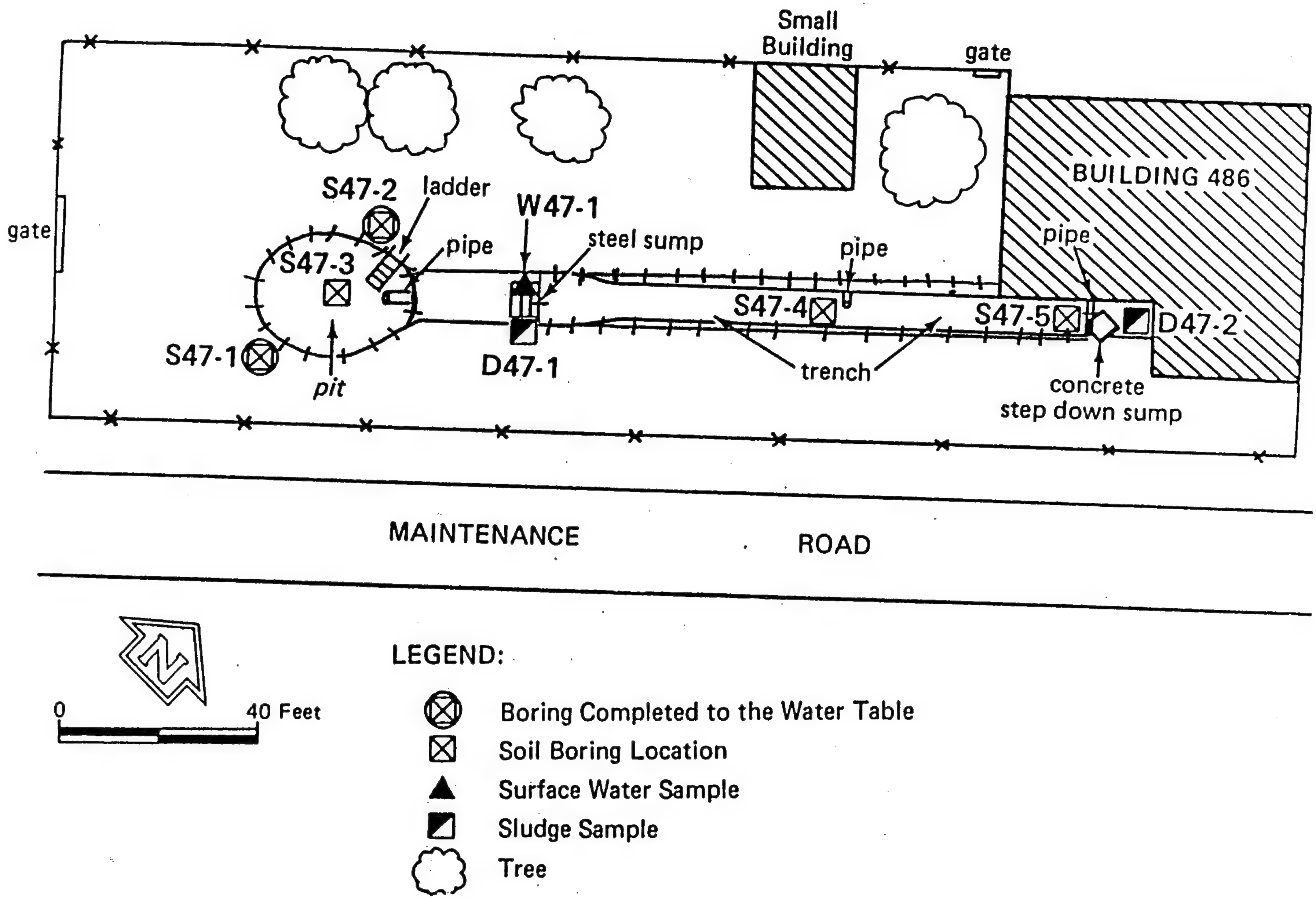
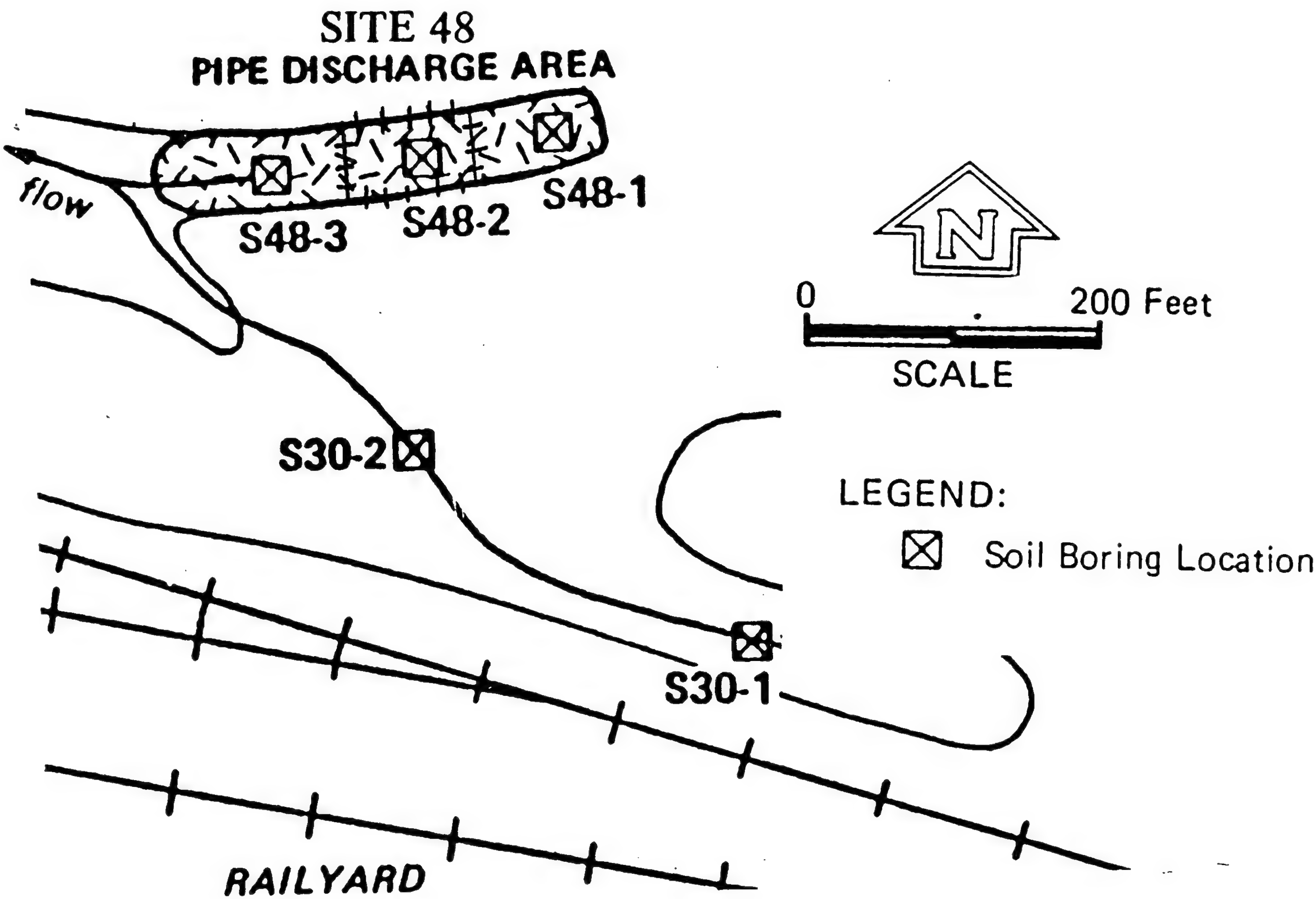


Figure B-6: Site 48, Pipe Discharge Area



Appendix C: Cost Estimates

Table C-1: Alternative 2A – Containment with Soil Cover

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Install barrier fencing				
Chain link fencing, 6' high	lf	2,000	15	30,000
Chain link gate	ea	6	218	1,308
Place clean on-site soil over contaminated areas (1)				
Mobilization and demobilization	acre	3	300	900
Load, haul, dump, and level	cy	5,456	6	32,733
Revegetation	100 sf	980	26	25,480
Contingency (25%) (3)				22,605
Total Capital Cost				***$113,027***
O&M Costs				
Five year review (2)	hr	80	80	6,400
Contingency (25%) (3)				1,600
Total O&M Cost				***$8,000***
Remedial Design/Planning				***$11,000***
Total Cost of Alternative (4)				**$132,000**

(1) Soil cover is 18 inches thick
(2) Cost of Five Year Review divided evenly over five years
(3) Refers to additional costs that may be incurred in implementation.
(4) Totals rounded to nearest thousand

Table C-2: Alternative 2B – Containment with Engineered Cap

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Install barrier fencing				
Chain link fencing, 6' high	lf	2,000	15	30,000
Chain link gate	ea	6	218	1,308
Place clay cap over contaminated areas (1)				
Mobilization and demobilization	acre	3	300	900
Haul, dump, and grade	sf	98,200	0.6	58,920
Place sand and gravel over clay cap (2)				
Mobilization and demobilization	acre	3	300	900
Haul, dump, and grade	sf	98,200	0.3	29,460
Revegetation	100 sf	980	26	25,480
Contingency (25%) (4)				36,742
Total Capital Cost				***$183,710***
O&M Costs				
Five year review (3)	hr	80	80	6,400
Contingency (25%) (4)				1,600
Total O&M Cost				***$8,000***
Remedial Design/Planning				***$19,000***
Total Cost of Alternative (5)				**$211,000**

(1) 24-inch thick clay layer
(2) 12-inch layer of sand/gravel
(3) The cost for the Five Year Review has been divided evenly over five years
(4) Refers to additional costs that may be incurred in implementation.
(5)Totals rounded to nearest thousand

Table C-3: Alternative 3A – On-Site Treatment – Solidification/Stabilization

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Excavate contaminated soils				
Excavate contaminated soil	cy	4,910	8	39,280
Haul excavated contaminated soil on-site and stockpile				
Haul and dump, 2-mile round trip	cy	4,910	4	19,640
Liner	sf	8,838	0.38	3,358
Cover	sf	11,293	0.38	4,291
Soil wash to reduce volume				
Conveyor (incl. feed hopper)	ea	1	9600	9,600
Debris screen	ea	1	20400	20,400
Spiral classifier	ea	1	30000	30,000
Dewatering conveyor	ea	1	9600	9,600
Overflow sump	ea	1	2400	2,400
Slurry pump	gpm	70	18	1,260
Sludge pump	gpm	20	144	2,880
Settling tank	gal	4,200	2	8,400
Chemical feed system	ea	1	12000	12,000
Filter press	cy/day	20	4560	91,200
Recycle water tank	gal	1,100	2	2,200
Water recycle pump	gpm	70	18	1,260
Piping, electrical, and instrumentation		1	34416	34,416
Treatability testing/engineering				100,000
Separate, stockpile, and cover washed fractions (1)				
Load, haul, and dump (2 mile round trip)	cy	982	4	3,928
Liner	sf	1,768	0.38	672
Cover	sf	2,259	0.38	858
Analysis of washed fractions				
Sample collection	hrs	320	30	9,600
Supervision	hrs	30	50	1,500
Sample analysis	sample	150	150	22,500
Data review and reporting	hrs	30	65	1,950
Solidification/Stabilization of contaminated fraction				
Mobilization and demobilization	ea	2	10000	20,000
Site preparation	cy	982	2.4	2,357
System startup	cy	982	1	982
Treatability testing				50,000
Off-Site Landfill disposal of S/S treatment products (2)				
Mobilization and demobilization	ea	2	500	1,000
Haul and dump	cy	1,178	8	9,427
Disposal of treatment products	cy	1,178	56	65,990
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	4,910	4	19,640
Level and grade filled pits	cy	4,910	2	9,820
Vegetation	100 sf	980	26	25,480
Contingency (25%) (3)				159,473
Total Capital Cost				***$797,363***

Table C-3: Alternative 3A – On-Site Treatment – Solidification/Stabilization (cont)

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
O&M Costs				
Soil wash				
Labor	hrs	4,600	45	207,000
Maintenance, power, supplies, cleanup, and miscellaneous				63,162
Solidification/Stabilization				
Labor	1000 cy	0.98	27800	27,300
Consumables	1000 cy	0.98	26000	25,532
Equipment Rental	week	10.00	6500	65,000
Decon/cleanup waste treatment/disposal	1000 cy	0.98	700	687
Analytical	1000 cy	0.98	2100	2,062
Contingency (25%) (3)				97,686
Total O&M Cost				***$488,429***
Remedial Design/Planning				***$129,000***
Total Cost of Alternative (4)				**$1,415,000**

(1) Assumes the contaminated fraction is 20% of the total soil washed volume
(2) Assumes that solidification/stabilization will increase soil volume by 20%
(3) Refers to additional costs that may be incurred in implementation.
(4) Totals rounded to nearest thousand
Source: Arthur D. Little, Inc.

Table C-4: Alternative 3B – On-Site Treatment – Solidification/Stabilization

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Excavate contaminated soils				
Excavate contaminated soil	cy	4,910	8	39,280
Haul excavated contaminated soil on-site				
Haul and dump, 2-mile round trip	cy	4,910	4	19,640
Liner	sf	8,838	0.38	3,358
Cover	sf	11,293	0.38	4,291
Soil wash to reduce volume (see equipment breakout on Table C-3)				
Equipment				225,616
Treatability testing/engineering				100,000
Separate, stockpile, and cover washed fractions (1)				
Load, haul, and dump (2 mile round trip)	cy	982	4	3,928
Liner	sf	1,768	0.38	672
Cover	sf	2,259	0.38	858
Analysis of washed fractions				
Sample collection	hrs	320	30	9,600
Supervision	hrs	30	50	1,500
Sample analysis	sample	150	150	22,500
Data review and reporting	hrs	30	65	1,950
Solidification/Stabilization of contaminated fraction				
Mobilization and demobilization	ea	2	10000	20,000
Site preparation	cy	982	2.4	2,357
System startup	cy	982	1	982
Treatability testing				50,000
On-Site disposal of S/S treatment products in active landfill (Option 1)				
Haul and dump (2)	cy	1,178	4	4,714
On-Site disposal of S/S treatment products in new landfill (Option 2)				
Engineering design and construction of new landfill (3)				1,300,000
Haul and dump (2)	cy	1,178	4	4,714
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	4,910	4	19,640
Level and grade filled pits	cy	4,910	2	9,820
Vegetation	100 sf	980	26	25,480
Contingency (25%) – Option 1 (5)				141,547
Contingency (25%) – Option 2 (5)				466,547
Total Capital Cost (Option 1)				***$707,733***
Total Capital Cost (Option 2)				***$2,332,733***

Table C-4: Alternative 3B – On-Site Treatment – Solidification/Stabilization (cont)

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
O&M Costs				
Soil wash				
Labor	hrs	4,600	45	207,000
Maintenance, power, supplies, cleanup, and miscellaneous				63,162
Solidification/Stabilization				
Labor	1000 cy	0.98	27800	27,300
Consumables	1000 cy	0.98	26000	25,532
Equipment Rental	week	10.00	6500	65,000
Decon/cleanup waste treatment/disposal	1000 cy	0.98	700	687
Analytical	1000 cy	0.98	2100	2,062
Five Year Review (4)				
Data review and reporting	hrs	80.00	80	6,400
Contingency (25%) (5)				99,286
Total O&M Cost				***$496,429***
Remedial Design/Planning (Option 1)				***$121,000***
Remedial Design/Planning (Option 2)				***$283,000***
Total Cost of Alternative (Option 1) (6)				**$1,325,000**
Total Cost of Alternative (Option 2) (6)				**$3,112,000**

(1) Assumes the contaminated fraction is 20% of the total soil washed volume
(2) Assumes that solidification/stabilization will increase soil volume by 20%
(3) New Landfill is a Subtitle D facility with 60 mil thick double synthetic liners
(4) Cost for Five Year Review has been divided evenly over five years
(5) Refers to additional costs that may be incurred in implementation
(6)Totals rounded to nearest thousand
Source: Arthur D. Little, Inc.

Table C-5: Alternative 3C – On-Site Treatment – Solidification/Stabilization

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Excavate contaminated soils				
Excavate contaminated soil	cy	4,910	8	39,280
Haul excavated contaminated soil on-site				
Haul and dump, 2-mile round trip	cy	4,910	4	19,640
Liner	sf	8,838	0.38	3,358
Cover	sf	11,293	0.38	4,291
Solidification/Stabilization				
Mobilization and demobilization	ea	2	10000	20,000
Site preparation	cy	4,910	2.4	11,784
System startup	cy	4,910	1	4,910
Treatability testing				50,000
Off-Site Landfill disposal of S/S treatment products (1)				
Mobilization and demobilization	ea	2	500	1,000
Haul and dump	cy	5,892	8	47,136
Disposal of treatment products	cy	5,892	56	329,952
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	4,910	4	19,640
Level and grade filled pits	cy	4,910	2	9,820
Vegetation	100 sf	980	26	25,480
Contingency (25%) (2)				146,573
Total Capital Cost				***$732,865***
O&M Costs				
Solidification/Stabilization				
Labor	1000 cy	4.91	27800	136,498
Consumables	1000 cy	4.91	26000	127,660
Equipment Rental	week	10.00	6500	65,000
Decon/cleanup waste treatment/disposal	1000 cy	4.91	700	3,437
Analytical	1000 cy	4.91	2100	10,311
Contingency (25%) (2)				85,727
Total O&M Cost				***$428,633***
Remedial Design/Planning				***$116,000***
Total Cost of Alternative (3)				**$1,278,000**

(1) Assumes that solidification/stabilization will increase soil volume by 20%
(2) Refers to additional costs that may be incurred in implementation
(3)Totals rounded to nearest thousand
Source: Arthur D. Little, Inc.

Table C-6: Alternative 3D – On-Site Treatment – Solidification/Stabilization

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Excavate contaminated soils				
Excavate contaminated soil	cy	4,910	8	39,280
Haul excavated contaminated soil on-site				
Haul and dump, 2-mile round trip	cy	4,910	4	19,640
Liner	sf	8,838	0.38	3,358
Cover	sf	11,293	0.38	4,291
Solidification/Stabilization (1)				
Mobilization and demobilization	ea	2	10000	20,000
Site preparation	cy	4,910	2.4	11,784
System startup	cy	4,910	1	4,910
Treatability testing				50,000
On-Site disposal of S/S treatment products in active landfill (Option 1)				
Haul and dump (2)	cy	5,892	4	23,568
On-Site disposal of S/S treatment products in new landfill (Option 2)				
Engineering design and construction of new landfill (3)				1,300,000
Haul and dump (2)	cy	5,892	4	23,568
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	4,910	4	19,640
Level and grade filled pits	cy	4,910	2	9,820
Vegetation	100 sf	980	26	25,480
Contingency (25%) – Option 1 (5)				57,943
Contingency (25%) – Option 2 (5)				382,943
Total Capital Cost (Option 1)				***$289,715***
Total Capital Cost (Option 2)				***$1,914,715***
O&M Costs				
Solidification/Stabilization				
Labor	1000 cy	4.91	27800	136,498
Consumables	1000 cy	4.91	26000	127,660
Equipment Rental	week	10.00	6500	65,000
Decon/cleanup waste treatment/disposal	1000 cy	4.91	700	3,437
Analytical	1000 cy	4.91	2100	10,311
Five Year Review (4)				
Data review and reporting	hrs	80.00	80	6,400
Contingency (25%) (5)				87,327
Total O&M Cost				***$436,633***
Remedial Design/Planning (Option 1)				***$73,000***
Remedial Design/Planning (Option 2)				***$235,000***
Total Cost of Alternative – Option 1(6)				**$800,000**
Total Cost of Alternative – Option 2 (6)				**$2,586,000**

(1) Assumes that solidification/stabilization will increase soil volume by 20%
(2) Assumes that solidification/stabilization will increase soil volume by 20%
(3) New Landfill is a Subtitle D facility with 60 mil thick double synthetic liners
(4) Cost of Five Year Review has been divided evenly over five years
(5) Refers to additional costs thay may be incurred in implementation
(6) Totals rounded to nearest thousand

Source: Arthur D. Little, Inc.

Table C-7: Alternative 4A – On-Site Treatment – Incineration and Solidification/Stabilization

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Excavate contaminated soils				
Excavate contaminated soil	cy	4,910	8	39,280
Haul excavated contaminated soil on-site and stockpile				
Haul and dump, 2-mile round trip	cy	4,910	4	19,640
Liner	sf	8,838	0.38	3,358
Cover	sf	11,293	0.38	4,291
Soil wash to reduce volume				
Conveyor (incl. feed hopper)	ea	1	9600	9,600
Debris screen	ea	1	20400	20,400
Spiral classifier	ea	1	30000	30,000
Dewatering conveyor	ea	1	9600	9,600
Overflow sump	ea	1	2400	2,400
Slurry pump	gpm	70	18	1,260
Sludge pump	gpm	20	144	2,880
Settling tank	gal	4,200	2	8,400
Chemical feed system	ea	1	12000	12,000
Filter press	cy/day	20	4560	91,200
Recycle water tank	gal	1,100	2	2,200
Water recycle pump	gpm	70	18	1,260
Piping, electrical, and instrumentation		1	34416	34,416
Treatability testing/engineering				100,000
Separate, stockpile, and cover washed fractions (1)				
Load, haul, and dump (2 mile round trip)	cy	982	4	3,928
Liner	sf	1,768	0.38	672
Cover	sf	2,259	0.38	858
Analysis of washed fractions				
Sample collection	hrs	160	30	4,800
Supervision	hrs	30	50	1,500
Sample analysis	sample	75	150	11,250
Data review and reporting	hrs	30	65	1,950
Incinerate organic fraction (2)		982		
Mobilization	cy	442	38	16,792
Site preparation	cy	442	124	54,796
Trial burns	ea	1	200000	200,000
Demobilization	cy	442	38	16,792
Haul incinerator residuals and metal-contaminated fraction to S/S (3)				
Load, haul, and dump (2 mi round trip)	cy	849	4	3,398
Solidification/Stabilization of incinerator residuals and metal-contaminated fraction				
Mobilization and demobilization	ea	2	10000	20,000
Site preparation	cy	849	2.4	2,039
System startup	cy	849	1	849
Treatability testing				50,000
Off-Site Landfill disposal of S/S treatment products (4)				
Mobilization and demobilization	ea	2	500	1,000
Haul and dump	cy	1,019	8	8,155
Disposal of treatment products	cy	1,019	56	57,082
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	4,910	4	19,640
Level and grade filled pits	cy	4,910	2	9,820
Vegetation	100 sf	980	26	25,480
Contingency (25%) (6)				225,746
Total Capital Cost				***$1,128,732***

Table C-7: Alternative 4A – On-Site Treatment – Incineration and Solidification/Stabilization (continued)

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
O&M Costs				
Soil wash				
Labor	hrs	4,600	45	207,000
Maintenance, power, supplies, cleanup, and miscellaneous				63,162
Incineration				
Fuel	cy	250	270	67,500
Electricity	cy	250	40	10,000
Water	cy	250	10	2,500
Equipment Rental/Use (5)	week	10	17000	170,000
Solidification/Stabilization				
Labor	1000 cy	0.85	27800	23,614
Consumables	1000 cy	0.85	26000	22,085
Equipment Rental	week	10.00	6500	65,000
Decon/cleanup waste treatment/disposal	1000 cy	0.85	700	595
Analytical	1000 cy	0.85	2100	1,784
Contingency (25%) (6)				158,310
Total O&M Cost				***$791,550***
Remedial Design/Planning				***$192,000***
Total Cost of Alternative (7)				**$2,113,000**

(1) Assumes the contaminated fraction is 20% of the total soil washed volume
(2) Assumes that organic-contaminated fraction is 45% by volume
(3) Assumes that incinerator residuals are 70% of incinerator feed volume
(4) Assumes that solidification/stabilization will increase soil volume by 20%
(5) Includes transportation and labor
(6) Refers to additional costs that may be incurred in implementation
(7) Totals rounded to nearest thousand

Source: Arthur D. Little, Inc.

Table C-8: Alternative 4B – On-Site Treatment – Incineration andSolidification/Stabilization

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Excavate contaminated soils				
Excavate contaminated soil	cy	4,910	8	39,280
Haul excavated contaminated soil on-site and stockpile				
Haul and dump, 2-mile round trip	cy	4,910	4	19,640
Liner	sf	8,838	0.38	3,358
Cover	sf	11,293	0.38	4,291
Soil wash to reduce volume (see equipment breakout on Table C-10)				
Equipment				225,616
Treatability testing/engineering				100,000
Separate, stockpile, and cover washed fractions (1)				
Load, haul, and dump (2 mile round trip)	cy	982	4	3,928
Liner	sf	1,768	0.38	672
Cover	sf	2,259	0.38	858
Analysis of washed fractions				
Sample collection	hrs	160	30	4,800
Supervision	hrs	30	50	1,500
Sample analysis	sample	75	150	11,250
Data review and reporting	hrs	30	65	1,950
Incinerate organic fraction (2)		982		
Mobilization	cy	442	38	16,792
Site preparation	cy	442	124	54,796
Trial burns	ea	1	200000	200,000
Demobilization	cy	442	38	16,792
Haul incinerator residuals and metal-contaminated fraction to S/S (3)				
Load, haul, and dump (2 mi round trip)	cy	849	4	3,398
Solidification/Stabilization of incinerator residuals and metal-contaminated fraction				
Mobilization and demobilization	ea	2	10000	20,000
Site preparation	cy	849	2.4	2,039
System startup	cy	849	1	849
Treatability testing				50,000
On-Site disposal of S/S treatment products in active landfill (Option 1)				
Haul and dump (4)	cy	1,019	4	4,077
On-Site disposal of S/S treatment products in new landfill (Option 2)				
Engineering design and construction of new landfill (5)				1,300,000
Haul and dump (4)	cy	1,019	4	4,077
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	4,910	4	19,640
Level and grade filled pits	cy	4,910	2	9,820
Vegetation	100 sf	980	26	25,480
Contingency (25%)– Option 1 (7)				210,207
Contingency (25%) –Option 2 (7)				535,207
Total Capital Cost (Option 1)				***$1,051,033***
Total Capital Cost (Option 2)				***$2,676,033***

Table C-8: Alternative 4B – On-Site Treatment – Incineration andSolidification/Stabilization (continued)

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
O&M Costs				
Soil wash				
Labor	hrs	4,600	45	207,000
Maintenance, power, supplies, cleanup, and miscellaneous				63,162
Incineration				
Fuel	cy	250	270	67,500
Electricity	cy	250	40	10,000
Water	cy	250	10	2,500
Equipment Rental/Use	week	10	17000	170,000
Solidification/Stabilization				
Labor	1000 cy	0.85	27800	23,614
Consumables	1000 cy	0.85	26000	22,085
Equipment Rental	week	10.00	6500	65,000
Decon/cleanup waste treatment/disposal	1000 cy	0.85	700	595
Analytical	1000 cy	0.85	2100	1,784
Five Year Review (6)				
Data review and reporting	hrs	80.00	80	6,400
Contingency (25%) (7)				159,910
Total O&M Cost				***$799,550***
Remedial Design/Planning (Option 1)				***$185,000***
Remedial Design/Planning (Option 2)				***$348,000***
Total Cost of Alternative (Option 1) (8)				**$2,036,000**
Total Cost of Alternative (Option 2) (8)				**$3,824,000**

(1) Assumes the contaminated fraction is 20% of the total soil washed volume
(2) Assumes that organic-contaminated fraction is 45% by volume
(3) Assumes that incinerator residuals are 70% of incinerator feed volume
(4) Assumes that solidification/stabilization will increase soil volume by 20%
(5) New Landfill is a Subtitle D facility with 60 mil thick double synthetic liners
(6) The cost for the Five Year Review has been divided evenly over five years
(7) Refers to additional costs that may be incurred in implementation
(8) Totals rounded to nearest thousand

Source: Arthur D. Little, Inc.

Table C-9: Alternative 4C – On-Site Treatment – Incineration andSolidification/Stabilization

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Install barrier fencing (existing)				
Excavate contaminated soils				
Excavate contaminated soil	cy	4,910	8	39,280
Haul excavated contaminated soil on-site and stockpile				
Haul and dump, 2-mile round trip	cy	4,910	4	19,640
Liner	sf	8,838	0.38	3,358
Cover	sf	11,293	0.38	4,291
Incinerate organic soils (1)				
Mobilization	cy	2,210	38	83,961
Site preparation	cy	2,210	124	273,978
Trial burns	ea	1	200000	200,000
Demobilization	cy	2,210	38	83,961
Haul incinerator residuals and metal-contaminated soil to S/S (2)				
Load, haul, and dump (2 mi round trip)	cy	4,247	4	16,989
Solidification/Stabilization of incinerator residuals and metal-contaminated soil				
Mobilization and demobilization	ea	2	10000	20,000
Site preparation	cy	4,247	2.4	10,193
System startup	cy	4,247	1	4,247
Treatability testing				50,000
Off-Site Landfill disposal of S/S treatment products (3)				
Mobilization and demobilization	ea	2	500	1,000
Haul and dump	cy	5,097	8	40,773
Disposal of treatment products	cy	5,097	56	285,408
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	4,910	4	19,640
Level and grade filled pits	cy	4,910	2	9,820
Vegetation	100 sf	980	26	25,480
Contingency (25%) (5)				298,005
Total Capital Cost				***$1,490,025***

Table C-9: Alternative 4C – On-Site Treatment – Incineration andSolidification/Stabilization (continued)

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
O&M Costs				
Incineration				
Fuel	cy	1,120	270	302,400
Electricity	cy	1,120	40	44,800
Water	cy	1,120	10	11,200
Equipment Rental/Use (4)	week	10	17000	170,000
Solidification/Stabilization				
Labor	1000 cy	4.25	27800	118,071
Consumables	1000 cy	4.25	26000	110,426
Equipment Rental	week	10.00	6500	65,000
Decon/cleanup waste treatment/disposal	1000 cy	4.25	700	2,973
Analytical	1000 cy	4.25	2100	8,919
Contingency (25%) (5)				208,447
Total O&M Cost				***$1,042,236***
Remedial Design/Planning				***$253,000***
Total Cost of Alternative (6)				**$2,784,000**

(1) Assumes that organic-contaminated fraction is 45% by volume
(2) Assumes that incinerator residuals are 70% of incinerator feed volume
(3) Assumes that solidification/stabilization will increase soil volume by 20%
(4) Includes transportation and labor
(5) Refers to additional costs that may be incurred in implementation
(6) Totals rounded to nearest thousand
Source: Arthur D. Little, Inc.

Table C-10: Alternative 4D – On-Site Treatment – Incineration andSolidification/Stabilization

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Install barrier fencing (existing)				
Excavate contaminated soils				
Excavate contaminated soil	cy	4,910	8	39,280
Haul excavated contaminated soil on-site and stockpile				
Haul and dump, 2-mile round trip	cy	4,910	4	19,640
Liner	sf	8,838	0.38	3,358
Cover	sf	11,293	0.38	4,291
Incinerate organic soils (1)				
Mobilization	cy	2,210	38	83,961
Site preparation	cy	2,210	124	273,978
Trial burns	ea	1	200000	200,000
Demobilization	cy	2,210	38	83,961
Haul incinerator residuals and metal-contaminated soil to S/S (2)				
Load, haul, and dump (2 mi round trip)	cy	4,247	4	16,989
Solidification/Stabilization of incinerator residuals and metal-contaminated soil				
Mobilization and demobilization	ea	2	10000	20,000
Site preparation	cy	4,247	2.4	10,193
System startup	cy	4,247	1	4,247
Treatability testing				50,000
On-Site disposal of S/S treatment products in active landfill (Option 1)				
Haul and dump (3)	cy	5,097	4	20,386
On-Site disposal of S/S treatment products in new landfill (Option 2)				
Engineering design and construction of new landfill				1,300,000
Haul and dump (3)	cy	5,097	4	20,386
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	4,910	4	19,640
Level and grade filled pits	cy	4,910	2	9,820
Vegetation	100 sf	980	26	25,480
Contingency (25%)– Option 1 (5)				221,306
Contingency (25%) –Option 2 (5)				546,306
Total Capital Cost (Option 1)				***$1,106,531***
Total Capital Cost (Option 2)				***$2,731,531***

Table C-10: Alternative 4D – On-Site Treatment -- Incineration andSolidification/Stabilization (continued)

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
O&M Costs				
Incineration				
Fuel	cy	1,120	270	302,400
Electricity	cy	1,120	40	44,800
Water	cy	1,120	10	11,200
Equipment Rental/Use (4)	week	10	17000	170,000
Solidification/Stabilization				
Labor	1000 cy	4.25	27800	118,071
Consumables	1000 cy	4.25	26000	110,426
Equipment Rental	week	10.00	6500	65,000
Decon/cleanup waste treatment/disposal	1000 cy	4.25	700	2,973
Analytical	1000 cy	4.25	2100	8,919
Five Year Review				
Data review and reporting	hrs	80.00	80	6,400
Contingency (25%) (5)				210,047
Total O&M Cost				***$1,050,236***
Remedial Design/Planning (Option 1)				***$216,000***
Remedial Design/Planning (Option 2)				***$378,000***
Total Cost of Alternative (Option 1) (6)				**$2,371,000**
Total Cost of Alternative (Option 2) (6)				**$4,158,000**

(1) Assumes that organic-contaminated fraction is 45% by volume

(2) Assumes that incinerator residuals are 70% of incinerator feed volume

(3) Assumes that solidification/stabilization will increase soil volume by 20%

(4) Includes transportation and labor

(5) Refers to additional costs that may be incurred in implementation

(6) Totals rounded to nearest thousand

Source: Arthur D. Little, Inc.

Table C-11: Alternative 5A – Off-Site and On-Site Treatment

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Excavate contaminated soils				
Excavate contaminated soils	cy	4,910	8	39,280
Analysis of soil to segregate				
Sample collection	hrs	40	30	1,200
Supervision	hrs	40	50	2,000
Sample analysis	sample	10	500	5,000
Data review and reporting	hrs	20	65	1,300
Haul excavated contaminated soil on-site to stockpile				
Haul and dump	cy	4,910	4	19,640
Liner	sf	8,838	0.38	3,358
Cover	sf	11,293	0.38	4,291
Haul organic-only contaminated soils off-site and treat				
Mobilization and demobilization	ea	2	500	1,000
Load	cy	520	2	1,040
Haul contaminated soils off-site (60 mile round trip)	cy	520	18	9,360
Incineration of soil	cy	520	1500	780,000
Solidification/Stabilization of metal-contaminated soil				
Mobilization and demobilization	ea	2	10000	20,000
Site preparation	cy	4,390	2.4	10,536
System startup	cy	4,390	1	4,390
Treatability testing				50,000
Off-Site landfill disposal of S/S residues (1)				
Mobilization and demobilization	ea	2	500	1,000
Haul and dump	cy	5,268	8	42,144
Disposal of treatment products	cy	5,268	56	295,008
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	4,910	4	19,640
Level and grade filled pits	cy	4,910	2	9,820
Vegetation	100 sf	980	26	25,480
Contingency (25%)				336,372
Total Capital Cost				***$1,681,860***
O&M Costs				
Solidification/Stabilization				
Labor	1000 cy	4.39	27,800	122,042
Consumables	1000 cy	4.39	26,000	114,140
Equipment Rental	week	10.00	6,500	65,000
Effluent Treatment/Disposal	1000 cy	4.39	700	3,073
Analytical	1000 cy	4.39	2,100	9,219
Five Year Review				
Data review and reporting	hrs	80.00	80	6,400
Contingency (25%) (2)				79,969
Total O&M Cost				***$399,843***
Remedial Design/Planning				***$208,000***
Total Cost of Alternative (3)				**$2,289,000**

(1) Assumes that solidification/stabilization will increase soil volume by 20%
(2) Refers to additional costs that may be incurred in implementation
(3) Totals rounded to nearest thousand
Source: Arthur D. Little, Inc.

Table C-12: Alternative 5B – Off-Site and On-Site Treatment

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Excavate contaminated soils				
Excavate contaminated soils	cy	4,910	8	39,280
Analysis of soil to segregate				
Sample collection	hrs	40	30	1,200
Supervision	hrs	40	50	2,000
Sample analysis	sample	10	500	5,000
Data review and reporting	hrs	20	65	1,300
Haul excavated contaminated soil on-site to stockpile				
Haul and dump	cy	4,910	4	19,640
Liner	sf	8,838	0.38	3,358
Cover	sf	11,293	0.38	4,291
Haul organic-only contaminated soils off-site and treat				
Mobilization and demobilization	ea	2	500	1,000
Load	cy	520	2	1,040
Haul contaminated soils off-site (60 mile round trip)	cy	520	18	9,360
Incineration of soil	cy	520	1500	780,000
Solidification/Stabilization of metal-contaminated soil				
Mobilization and demobilization	ea	2	10000	20,000
Site preparation	cy	4,390	2.4	10,536
System startup	cy	4,390	1	4,390
Treatability testing				50,000
On-Site disposal of S/S treatment products and nonhazardous soils in active landfill (Option 1)				
Haul and dump (1)	cy	5,268	7	36,876
On-Site disposal of S/S treatment products and nonhazardous soil in new landfill (Option 2)				
Engineering design and construction of new landfill (2)				1,300,000
Haul and dump (1)	cy	5,268	7	36,876
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	4,910	4	19,640
Level and grade filled pits	cy	4,910	2	9,820
Vegetation	100 sf	980	26	25,480
Contingency (25%) – Option 1(3)				261,053
Contingency (25%) – Option 2 (3)				586,053
Total Capital Cost (Option 1)				***$1,305,265***
Total Capital Cost (Option 2)				***$2,930,265***
O&M Costs				
Solidification/Stabilization				
Labor	1000 cy	4.39	27,800	122,042
Consumables	1000 cy	4.39	26,000	114,140
Equipment Rental	week	10.00	6,500	65,000
Decon/cleanup waste treatment/disposal	1000 cy	4.39	700	3,073
Analytical	1000 cy	4.39	2,100	9,219
Five Year Review				
Data review and reporting	hrs	80.00	80	6,400
Contingency (25%) (3)				79,969
Total O&M Cost				***$399,843***
Remedial Design/Planning (Option 1)				***$171,000***
Remedial Design/Planning (Option 2)				***$333,000***
Total Cost of Alternative (Option 1) (4)				**$1,876,000**
Total Cost of Alternative (Option 2) (4)				**$3,663,000**

(1) Assumes that solidification/stabilization will increase soil volume by 20%
(2) New landfill is a Subtitle D facility with 60 mil thick double synthetic liners
(3) Refers to additional costs that may be incurred in implementation
(4) Totals rounded to nearest thousand
Source: Arthur D. Little, Inc.

Table C-13: Alternative 6 – Off-Site Treatment and Disposal

Description	Unit	Total Units	Unit Cost (1993 $)	Total Cost (1993 $)
Capital Costs				
Excavate contaminated soils				
Excavate contaminated soil	cy	4,910	8	39,280
Analysis of soil to segregate according to hazardous characteristics				
Sample collection	hrs	60	30	1,800
Supervision	hrs	40	50	2,000
Sample analysis	sample	20	500	10,000
Data review and reporting	hrs	40	65	2,600
Haul excavated contaminated soil on-site to stockpile				
Haul and dump	cy	4,910	4	19,640
Liner	sf	8,838	0.38	3,358
Cover	sf	11,293	0.38	4,291
Haul excavated and segregated soils off-site				
Mobilization and demobilization	ea	2	500	1,000
Load	cy	4,910	2	9,820
Haul contaminated soils off-site (60 mile round trip)	cy	4,910	12	58,920
Off-Site treatment of hazardous soils (1)				
Solidification/stabilization	cy	2,455	160	392,800
Off-Site disposal of nonhazardous soils (1)				
Landfill	cy	2,455	56	137,480
Site Restoration				
Load, haul, dump clean soil into excavated pits	cy	4,910	4	19,640
Level and grade filled pits	cy	4,910	2	9,820
Vegetation	100 sf	980	26	25,480
Contingency (25%) (2)				184,482
Total Capital Cost				**$923,000**
O&M Costs				
There are no O&M costs associated with this alternative				
Remedial Design/Planning				**$92,000**
Total Cost of Alternative (3)				**$1,015,000**

(1) Assumes that 50% of soil is characterized as hazardous; 50% of soil is characterized as nonhazardous
(2) Refers to additional costs that may be incurred in implementation
(3) Totals rounded to nearest thousand
Source: Arthur D. Little, Inc.

Comment and Response Package
USEPA and DEQ Comments

Draft Final Feasibility Study For Miscellaneous Sites (OU5) at the Umatilla Depot Activity (UMDA)

Submitted to:

U.S. Army Environmental Center (USAEC), Aberdeen Proving Ground, Maryland

Revision 0
November 15, 1993

Arthur D. Little, Inc.
Acorn Park
Cambridge, Massachusetts
02140-2390

ADL Reference 67062

DAAA15-91-D-0016
Delivery Order No. 2

Comment and Response Package USEPA and DEQ Comments

Draft Final Feasibility Study for Miscellaneous Sites (OU5) at the Umatilla Depot Activity (UMDA)

R N Lambe
Program Manager, Robert Lambe

15 Nov 93
Date

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Task Manager, Armand Balasco

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Responses to U.S. Environmental Protection Agency (EPA) Technical Review Comments on Draft Final Feasibility Study for the Miscellaneous Sites(OU-5) at Umatilla Depot Activity

General Comments

...The areal and vertical extent of contamination for some of the sites in the miscellaneous sites operable unit are based on limited sampling data and generally do not account for past disposal structures (trenches , pits, and pads) that may have been backfilled or graded over. The actual area and volume of contaminated soils could be greater than the estimate in Appendix B. Therefore, it is recommended that additional field screening and sampling be performed concurrently with any remedial action to further define the extent of the contamination.

Response

On page 2-20, in section 2.3.2, first paragraph, it states, "...Many of the sites at the Miscellaneous Sites involve considerable areas and sampling represented a small subset of these areas. Consequently, it is important to note that these estimates are preliminary in nature due to the absence of sufficient data to fully delineate the vertical and areal extent of contamination. Therefore, it is recommended that additional field screening and sampling be performed concurrently with any remedial action to further define the extent of contamination."

Comment 1

Section 1.2.3, page 1-25. The test states that constituents were detected at several sites but were not above the certified reporting limits (CRL). The text should identify whether wastes were considered hazardous under the Resource Conservation and Recovery Act (RCRA) or whether they were considered other hazardous substances.

Response

This section 1.2.3, page 24, only identifies possible contaminants where later sections deal with the other questions.

Comment 2

Section 1.2.3, page 1-25. This section discusses the nature and extent of the contamination at each of the miscellaneous sites in OU-5. The text should identify the horizontal extent of contamination and the estimated volume of contaminated media to be addressed in the feasibility study.

Response

Section 1.2.3 summarizes the results of the RI and is supplemented by the results of the RA. Section 2.3.2 on pages 2-20 and 2-21 and Appendix B identify the horizontal extent of contamination and the estimated volume of contaminated media to be addressed in the feasibility study. To clarify, the development and presentation of the extent, depth, and estimated volume of contaminated media as presented in subsequent sections of the FS are referenced in the introductory paragraph of Section 1.2.3 to allow the reader to easily access this information.

Comment 3

Section 2.2.2, pages 2-2 through 2-15 (see response below)

Comment 4

Table 2-2, pages 2-5 through 2-7 (see response below)

Comment 5

Section 2.2.2.3, pages 2-9 through 2-14 (see response below)

Response

Comments 3 through 5 address inconsistencies in the presentation and evaluation of chemical, location, and action-specific ARARs. In response to these comments, Section 2.2.2 has been substantially revised. Specifically, the development, description, and presentation of the ARARs has been made consistent for each of the categories. In addition, the ARARs have been developed to address the remedial alternatives to be considered. The use of ARARs developed during the preparation of the FS for the Explosive Washout Lagoons has been deleted and replaced with ARARs relevant to the present FS.

Comment 6

Section 2.2.2.3.1, page 2-12 through 2-13. This section addresses the applicability of RCRA 40 CFR Part 261, Subpart D listed hazardous waste codes. The first paragraph states that listed wastes may have been managed at the sites, but because the RCRA listed wastes are only listed for reactivity and the soils no longer meet the definition of reactivity, these listed waste codes are not applicable. This section should also be amended to determine the applicability of the RCRA P- and U-listed waste codes for any unused pesticides that may have been disposed of at the sites...

Response

As part of the revision of Section 2.2.2, a discussion of the applicability of RCRA P- and U-listed waste codes is presented.

Comment 7

Section 2.2.2.3.1, pages 2-12 through 2-13. This section addresses the applicability of RCRA 40 CFR Section 261.24 toxicity characteristic hazardous waste codes to the contaminated soils. One toxicity characteristic waste was identified, D008 (lead). A number of other toxicity characteristic constituents... are also found at the sites. An explanation of the screening and elimination process applied to all toxicity characteristic constituents should be included.

Response

The discussion of applicability of RCRA to contaminated soils as presented in Section 2.2.2 has been expanded to include the potential applicability due to the presence of a number of heavy metals at the Miscellaneous Sites. Only limited analyses were performed in the RI to determine the applicability of RCRA to heavy metal-contaminated soil. Acknowledgement of the need for further determination to assess applicability is presented in Section 2.2.2.

Comment 8

Section 2.2.2.3.1., page 2-12, third to last paragraph. Concentrations of lead are reported in µg/g and mg/g.

Response

The correct value is µg/g, and this typographical error has been corrected.

Comment 9

Section 2.2.2.3.2, page 2-14, second paragraph. This paragraph includes the Clean Air Act and Oregon Air Pollution Control regulations as ARARs. The corresponding regulations should be cited.

Response

Citations for the relevant ARARs have been included in this discussion.

Comment 10

Section 2.2.4, page 2-16, third paragraph. The remedial action objectives for the miscellaneous sites are presented in this section. The second bullet states that if background or 1×10^{-6} total excess cancer risks are not feasible, then reduce excess cancer risks will be reduced to the lowest feasible level, within the range of 1×10^{-5} to 1×10^{-6}. It is proposed that the final level be determined based on a cost-benefit analysis, which is not described. Since the cost-benefit analysis would affect the remedial action and overall cleanup at the miscellaneous sites, the criteria and evaluation method to be used for this analysis should be presented.

Response

The wording referred to in this comment has been revised to reflect that the final level will be determined based on feasibility and cost. This does not necessarily imply the performance of a formal cost-benefit analysis; however, it does allow for the decision-makers to select a proposed remedy based on the feasibility and cost as developed in the detailed analysis of alternatives.

Comment 11

Section 2.3.2, page 2-19, first paragraph. The text states that the estimated areas and volumes of contaminated media requiring remediation are preliminary in nature because of the absence of sufficient data to fully delineate the vertical and area extent of contamination. Although depth is estimated for the vertical extent of contamination at each site, the text does not identify the deepest sample at each site. The vertical extent of contamination could be potentially greater if the deepest sample were contaminated and the depth of this sample were used as the vertical extent of contamination. The method for determining the vertical extent of contamination should be more clearly explained.

Table 2-6 lists the depths of contaminated soil from sample results at each site. The depths range from 0 to 9 feet below ground surface (bgs). A 25 percent contingency was applied to the soil volumes estimated in Appendix B. However, assuming the same horizontal extent, applying the contingency would only account for an increase of the vertical extent of less than 1 foot at sites with contamination less than 4 feet bgs.

Therefore, the contingency factor would only account for a small increase in the estimated vertical extent of contamination, and the estimated volumes may be significantly greater because of uncertainties associated with defining the vertical extent of contamination.

Since increasing the vertical extent of contamination would greatly increase the volume of contaminated media and associated treatment costs, and may impact the alternative selection, site specific uncertainties should be provided. Then the contingencies included to account for the site-uncertainties could be evaluated.

Response

The sample depths selected during the RI were not random but selected based on visible inspection as well as the historical background of the site. It is acknowledged that there are instances in which contamination was detected at the deepest sample analyzed; however, the contamination appears to be located in relatively shallow soils. It is felt that the application of an overall uncertainty factor to each site adequately accounts for variability (both areal and vertical) that might be present in this initial estimation of soil volumes to be remediated and provides for an initial estimation of volumes to allow for the conduct of the detailed analysis of alternatives and the development of comparative cost estimates.

Comment 12

Table 2-7, page 2-21. This table should include a footnote that states that the affected areas and the remediation volumes by site include a 25 percent contingency factor as applied in Appendix B.

Response

Table 2-7, page 2-23, now contains the footnote.

Comment 13

Section 2.4.2.2.6, page 2-42, second paragraph. The last sentence summarizes EPA's position on solidification and stabilization. Solidification and stabilization processes are applicable to soils contaminated with metals and other inorganics, in addition to nonvolatile and semivolatile organic compounds. EPA does not currently view the process as applicable for remediation of soils contaminated solely with volatile organic compounds, because the volatile organic compounds would be released during the mixing and curing process... This text should be supported by a published reference or revised.

Response

The cited statement was in error and has been deleted.

Comment 14

Section 4.2.1.3, page 4-8, second paragraph. Based on a technology review, the feasibility study assumes that soil washing will concentrate the volume of contaminated soil to 20 percent of the original soil volume. The text should state whether site-specific soil data were considered during the analysis of soil washing to reach the assumed 80 percent volume reduction in contaminated soil...

Response

The text has been revised to reflect that the 80 percent reduction in soil volume achievable by soil washing was based on a review of the technology for use on Deactivation Furnace Site soils at UMDA. Although particle size and contaminant distribution analyses were not performed on miscellaneous sites soils, it is assumed for the purpose of this evaluation that miscellaneous sites soils would be similar in nature to the soils at the Deactivation Furnace Site.

Comment 15

Section 4.2.7.1, page 4-40, first paragraph. Alternative 6 includes contaminated soil excavation and segregation of hazardous and nonhazardous soils before treatment or disposal. Significant handling requirements and associated costs would be incurred by stockpiling large volumes of soil. The feasibility study should consider whether existing data could be used or additional data collected to characterize soils as hazardous or nonhazardous before excavation, therefore eliminating the need to stockpile large volumes of excavated soils.and provide a more accurate basis for design.

Response

The text has been revised to reflect that the segregation of hazardous and nonhazardous soils will be based on existing data as well as additional confirmation sampling and analyses. Descriptions of alternatives that employ segregation of soils have been revised to reflect this. Cost estimates for these alternatives have been revised to include additional costs due to sampling. In addition, it is assumed that to the maximum extent possible, segregation will occur during excavation with confirmation analyses performed after excavation.

Comment 16

Section 4.3.2., page 4-47, first paragraph. The text states that alternative 3, 4, 5, and 6 would provide for permanent removal of contaminants from the miscellaneous sites. However, treated soils and residuals will remain on the site although disposal in the active or new on-site landfill as proposed in several of the options of alternatives 3, 4, and 5. Therefore, the long-term effectiveness of alternatives 3, 4, and 5 will depend on the effectiveness of the soil treatment technologies and the landfill performance.

Response

The cited text in Section 4.3.3, page 4-47 has been revised accordingly.

Comment 17

The comparative analysis of alternatives presents a relative rating of the remedial alternatives for each feasibility study evaluation criteria. Table 4-6 presents a summary of the estimated costs for each alternative and provides a clear comparison to augment remedy selection. A similar table for the other evaluation criteria, only summarizing major points or limitations, would also be helpful during remedy selection. The inclusion of such a table should be considered.

Response

Sections 4.3.1 and through 4.3.6 discusses the relative merits of the various alternatives for each of the NCP evaluation criteria in a concise fashion. Only cost details are sufficiently complicated to make tables a great aid to the reader.

Comment 18

Appendix B, Site 22 and 25-1. The area and volume calculations for Sites 22 and 25-I assume that the metals is confined to the surface and that a 1-foot-deep excavation will remove all the contaminated soils. The basis for this assumption should be provided since subsurface samples were not collected at sites 22 and 25-I.

Response

Since the ore was piled on bare ground at sites 22 and 25-I, assume the contamination (metals) is confined to the surface and that a one-foot excavation will remove it. Further sampling during the remedial design phase will be necessary to confirm that a one-foot excavation will remove the contaminant.

Comment 19

Appendix B, Sample 25-6. The worksheet indicates that sample 25-6 was located at the southeastern end of the former pile of thallium ore and assumes that only the surface of the southern quarter of the former pile is contaminated. The basis for excluding 75 percent of this pile should be stated. The basis for limiting excavation to 1 foot should also be stated since subsurface samples were not collected at this location.

Response

Since only sample 25-6 showed an exceedance for thallium in the former ore pile, assume only the southern quarter of the former ore pile is contaminated on the surface only and a one foot excavation will remove it. Further sampling during the remedial design phase will be necessary to confirm that an one-foot excavation will remove the contaminant.

Comment 20

The worksheet assumes that contamination at site 36 is confined directly under the discharge pipe where sample 36-1 was collected and extends vertically 3 feet deep. However, Figure B-3 does not display any other sample locations down gradient from the discharge pipe, and Table 2-6 indicates a depth of 0 feet (surface) for sample 36-1. Therefore, the rational for limiting the horizontal and vertical extent of contamination based on one sample location should be provided.

Response

This site has a steep grade below Bldg. 493 where paint sludge was discharged in two areas into Coyote Coulee. With the steep grade, the discharge probably didn't penetrate the ground very deeply or spread laterally too far. Assume contamination is confined directly under the discharge pipe where sample 36-1 was obtained and extends to only three feet deep. Further sampling during the remediation design will be necessary to confirm the assumption of contamination to only three feet and to determine if further contamination occurred down gradient from the site.

Comment 21

Appendix C. Additional sampling will be required for site characterization or confirmation sampling during remediation. An estimate for the cost of analytical sampling required during and after remedial action should be included.

Response

Costs for additional sampling and analyses beyond that specifically presented in the FS are included in the contingency cost allowances as part of the indirect capital cost. The text has been revised to include this clarification.

Comment 22

Appendix C, Tables C-3 through C-18. Contaminated soil volumes estimated in Appendix B and summarized in Table 2-7 included a 25 percent contingency factor. Cost estimates for alternatives 4, 5, 6, and 7 are based on the estimated volume plus contingency; it is estimated that a total of 26,800 cubic yards requires treatment. However, additional contingencies for loading and hauling contaminated soils are included in the cost estimates and ranged from 20 to 25 percent. It should be clarified whether these contingencies involve adjusting a clean soil cost estimate with a factor to compensate for contaminated soil or involve using an additional contingency factor. Finally, overall contingency of 25 percent is applied to the total capital costs and the

total operation and maintenance costs. Although this percentage is reasonable for a feasibility study estimate, the fact that other contingencies are included makes the overall contingency allowance misleading.

Response

Appropriate revisions have been made to the text to clarify the difference between factors applied as "uncertainties" and factors applied as "contingencies." The factors applied to soil volumes reflect an allowance made for uncertainties involved in the estimation of contaminated soil volumes. Contingencies applied to the capital and operation and maintenance costs include funds to cover costs resulting from unforeseen circumstances (e.g., weather conditions, contaminant not detected during site characterization, labor strikes or delays, etc.).

Comment 23

Appendix C, Table C-3, C-4 C-5, C-9, C-10 and C-11 Treatability study testing and engineering for soil washing is estimated at $200,000. The reference source for this estimate should be provided.

Response

This cost was estimated in error. A revised cost of $100,000 for treatability study testing has been included in the analysis.

Comment 24

Appendix C, Table C-5, C-8, C-11, C-14, and C-17. The cost estimates for on-site disposal in a new landfill include engineering design of $800,000 and landfill construction of $500,000. Typically engineering costs approximately 15 to 25 percent of capital costs. The reference source for this estimate should be provided.

Response

This cost breakdown is in error. The total cost of design and construction of the landfill is correctly estimated at $1,300,000 based on recent experience.

Responses to Oregon Department of Environmental Quality (DEQ) Technical Review Comments on Draft Final Feasibility Study for the Miscellaneous Sites (OU-5) at Umatilla Depot Activity

Comment 1

The potential land use restriction discussed in this report include a prohibition on future agricultural use. It should be noted that the Depot is located in an area that is primarily agricultural and that agriculture is a potential future land use under consideration by the Oregon Economic Development Department and others. Efforts should be made to restore contaminated areas at the Depot to levels that are compatible with surrounding land uses. Land uses restrictions should be considered only when cleanup is not practicable.

Response

Land use restrictions are to be used only when cleanup is not practicable.

Comment 2

DEQ believes that a variation of Alternatives 3 and 6 should also be considered. This option would include excavation, soil analysis, on-site treatment and disposal of hazardous waste, and on-site disposal of non-hazardous waste.

Response

This option variation is now covered in Alternative 3D while Alternative 6 remains an off-site option.

Comment 3

Section 1.2.1, Page 1-6, third bullet. Change "polychloro" to "polychloronated."

Response

The change has been made on page 1-6.

Comment 4

Section 1.2.5.1, page 1-31, last bullet. The second sentence seem to conflict with the data summary in Section 1.2.3. Several of these sites *do* contain contaminants of concern. Site 6 had hits for DDT and PCBs...

Response

The summary in Section 1.2.3 was for possible contaminants detected above the background or Certified Reporting Limits while Section 1.2.5.1 presents criteria that provide a more limited list of contaminants of concern.

Comment 5

Tables 1-7 and 1-8, pages 1-46 and 1-48. These tables are inconsistent with respect to the total excess cancer risk for sites 27, 37, and 45.

Response

The tables 1-7 and 1-8 have been corrected.

Comment 6

Table 2-3, pages 2-10 and 2-11. Change "hazardous waste to "RCRA hazardous waste throughout the discussion of 40 CFR 262, 263, and 264.

Response

All changes to RCRA hazardous waste were completed.

Comment 7

Table 2-5, page 2-17. Oregon's Numerical Soil Cleanup Levels have been incorrectly used in this table...In, summary, it would be more appropriate to calculate risk-based cleanup levels for the Miscellaneous Sites than to reference Oregon's numerical standards.

Response

Table 2-5 uses risk-based cleanup levels rather than Oregon's numerical standards

Comment 8

Section 2.4.2.1, page 2-30, second full paragraph. Change the second sentence to read: As described...some Miscellaneous Sites soils containing lead (sites 22 and 47)...

Response

In the second full paragraph under On-Site Disposal of Section 2.4.2.1, the corrected sentence reads "As described in Section 2.2.2.3.1, Soil as Hazardous Waste, some Miscellaneous Sites soils containing lead (sites 22 and 47) potentially exhibit the toxicity characteristic and, as such, land disposal of these contaminated soils may be prohibited."

Comment 9

Section 2.4.2.1, page 2-32, first bullet. Change reference number to 23.

Response

In Section 2.4.2.1, the first dash starting with "...Slurry-phase treatment..." has its reference number corrected to 23.

Comment 10

Section 2.4.2.2.8, page 2-45, first full paragraph. Confirm reference number 40, this seems to be report dealing with solidification/stabilization. In the draft FS, this reference was to a report by McGowen and Ross, 1991.

Response

In Section 2.4.2.1, the full paragraph entitled "Cost," the reference was corrected to 38 that was also cited for other costs in the paragraph.

Comment 11

Section 3.2, page 3-1. Would it actually be necessary to fence the sites or would just restricting the land use suffice (e.g., prohibiting excavation activities)? Once the contaminated soil was covered, there would be no route for exposure, unless the cover was disturbed.

Response

In Section 3.2, fencing may not be necessary and institutional controls are not the preferred alternative, but it is a preferred method of the Army to restrict access to the sites. In addition, Comment 14 requires the cost of fencing for Alternative 2B.

Comment 12

Section 4.2.1.3, page 4-8,. Change reference number 28A to 28 in three locations on this page.

Response

The reference number was corrected to 28 in two cases and was corrected to 31 where this was appropriate.

Comment 13

Section 4.2.1.5, page 4-13, first full paragraph. The most recent draft closure plan for the Active Landfill calls for it to remain open for receipt of cleanup wastes until 1998.

Response

In Section 4.2.1.5, it notes that the Active Landfill can remain open for receipt of cleanup wastes until 1998.

Comment 14

Table 4-1, page 4-19. The contingency capital cost for Alternative 2A is not consistent with Table C-1 in Appendix C. Also, capital costs for Alternative 2B should include costs for fencing and revegetation. Total capital costs and total costs for Alternatives 2A and 2B need to be revised to reflect these changes.

Response

The Table 4-1 is now consistent with Table C-1 and the capital costs for Alternative 2B includes fencing and revegetation.

Comment 15

Figure 4-9, page 4-37. Shouldn't there be a soil analysis step? How will you confirm that soils contain only organic or only inorganic contamination?

Response

A soil analysis step now is shown in Figure 4-9.

Comment 16

Section 4.2.7.2, page 4-43, third paragraph. A properly designed and constructed landfill would provide some reduction of mobility (i.e., a liner and cap). This comment also applies to the sixth paragraph on page 4-44.

Response

The reduction in mobility caused by a properly designed and constructed landfill (i.e., a liner and cap) is noted in both places.

Comment 17

Section 4.2.7.2, page 4-44, third paragraph. Change "no risks" to "no unacceptable risks." There will be some residual risk.

Response

In Section 4.2.7.2 under the paragraph starting with Long-Term Effectiveness and Permanence, the wording was changed to "no unacceptable risks."

Comment 18

Section 4.3.4, page 4-48. Alternative 2 would result in some reduction in contaminant mobility, especially if an engineered cap were applied.

Response

In Section 4.3.4, it is stated that Alternative 2 would result in some reduction in contaminant mobility.

Comment 19

Appendix C - General Comments

A. Excavation Costs should b e included as a capital cost on Tables C-3 through C-17.

B. Unit costs for "load haul, and dump" are not used consistently among different alternatives. Explain how these unit costs are established and why there are variations.

C. Mobilization and demobilization total units vary among different line items of the alternatives. Explain how total units for mobilization and demobilization are established and why there are variations.

D. Unit costs for "contingency for contaminated soil" are not used consistently among the different line items of the alternatives. Explain how the unit costs are established and why there are variations.

Response

Appendix C - General Comments

A. Excavation costs are now included in the Tables in Appendix C.

B. The differences in load, haul, and dump change with the distance the material is hauled in the different alternatives.

C. The mobilization and demobilization costs depend on the size, complexity, and amount of labor to mobilize and demobilize the various operations involved in the alternative.

D. The contingency at 25% of both the capital costs and the operating and maintenance costs refer to additional costs that may be incurred in implementation process.

Comments 20 through 23

These comments address inconsistencies and need for clarification of cost items presented in Appendix C. The tables in Appendix C have been revised accordingly to address all inconsistencies and needed clarifications.

Response

The general comments for Appendix C address various inconsistencies and need for clarification of some line items in Appendix C. This appendix has been revised to correct the inconsistencies and errors. The cost of treatability studies for soil washing have been reduced to $100,000 to reflect DEQ and EPA comments.

Comment 24

Table C-3. The text (page 4-11) describes the use of a plastic-lined trench as a stockpile area for stabilized soils. The capital costs for preparation and materials for the stockpile area are not included on this table. This comment also applies to other alternatives where soil solidification/stabilization is proposed.

Response

As shown in Section 4.2.1.5, the text addressing the method of managing the stabilization/solidification treatment products prior to their disposal has been revised/corrected. The revision reflects that the treatment products are discharged to a dump truck or transportable container for transport to the final disposal area.

Comments 25 through 38

These comments address inconsistencies and need for clarification of cost items presented in Appendix C. The tables in Appendix C have been revised accordingly to address all inconsistencies and needed clarifications.

Comment 39

Tables C-18. What are the estimated analytical costs to determine if soil is RCRA Hazardous Waste or not?

Response

The cost for these analytical determinations are presented in the revised Appendix C tables.

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November 15, 1993

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Reference: TEPS Contract No. DAAA15-91-D-0016
Deliver Order No. 2, Feasibility Study (FS) and RCRA Corrective Measures Study (CMS) of Umatilla Army Depot Activity (UMDA)
ADL Reference No. 67062

Dear Mr. Kim:

Amsterdam
Brussels
Cambridge, U.K.
Cambridge, U.S.
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Wiesbaden

Enclosed please find 12 copies of the Final Feasibility Study for Miscellaneous Sites (Operable Unit 5) which is a deliverable under the referenced contract. This study was prepared under the direction of Mr. Armand Balasco, Task Manager. This Final Feasibility Study reflects revisions made to the Draft Final Feasibility Study in accordance with comments received from the U.S. Environmental Protection Agency (EPA) and the Oregon Department of Environmental Quality (ODEQ). A summary of responses to these comments is also enclosed.

At your request, copies of this Final Feasibility Study and summary of response to comments are being sent by overnight delivery to Mr. Jeff Rodin, EPA (2 copies); Mr. William Dana, ODEQ (2 copies); Mr. Mark Daugherty, UMDA (2 copies); and Mr. Mike Nelson, U.S. Army Corps of Engineers (USACE)-Seattle District (2 copies).

If you have any questions, please call me at 617/498-5498 or Mr. Balasco at 617/498-5390.

Sincerely,

R N Lambe

Robert N. Lambe, Ph.D
TEPS Program Manager

RNL/jmw
Enclosures

cc: Armand Balasco, ADL (w/enclosures)
Raymond Machacek, ADL (w/enclosures)
Jeff Rodin, EPA (w/enclosures)
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